

Characterization of MPPCs Detectors in Japan

25/Sep/2008, Pixel 2008 in FNAL
K. KOTERA from Calice group

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Ele.Mag. Calorimeter in ILC

Requirements

→ Particle Flow Analysis

- 10 mm x 10 mm granularity
- linearity of response to particle energy

→ Tolerance for Magnetic field (3-5T)

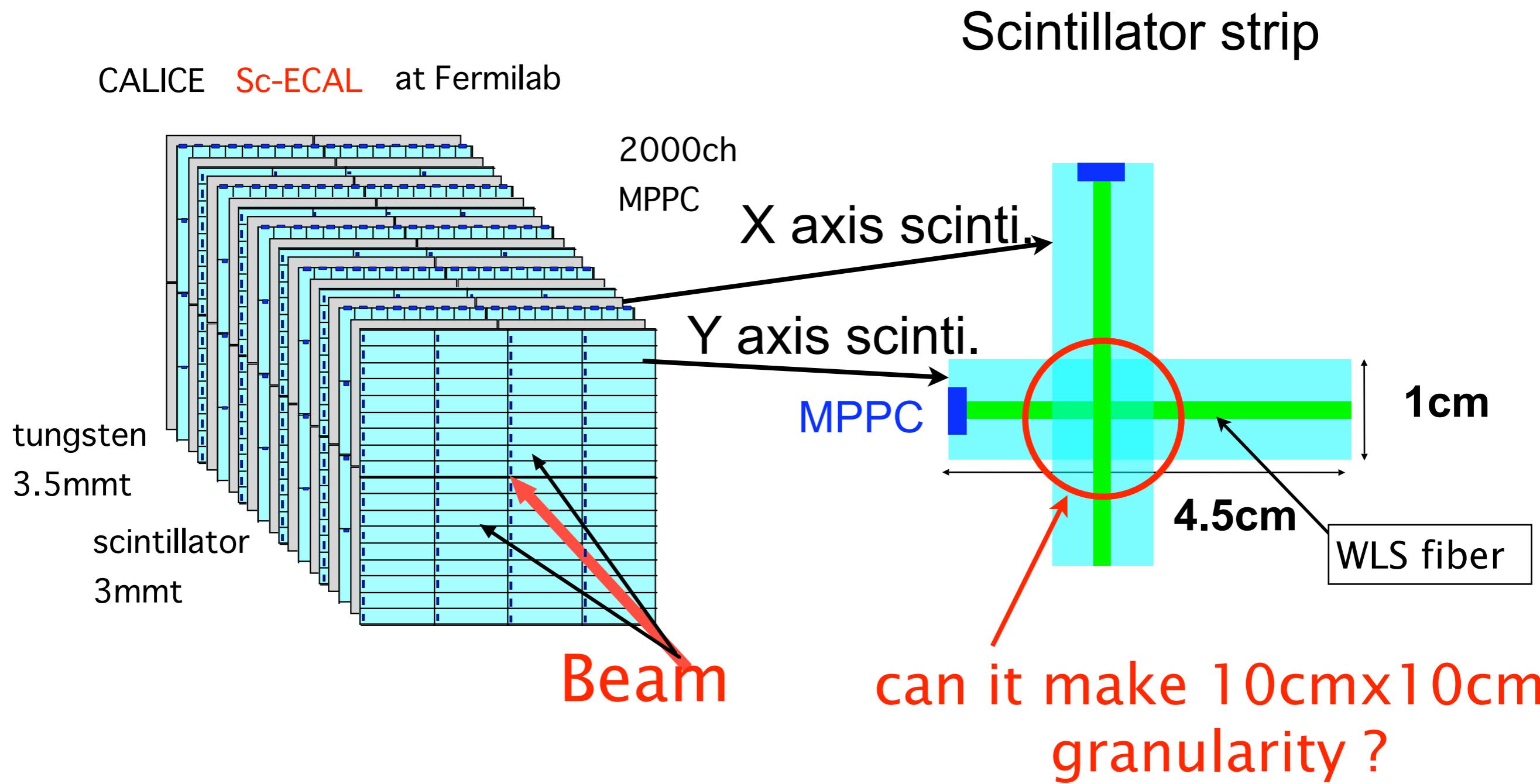
- PMT is not available

→ Practical cost

Our suggestion

- Sampling Cal. with 10 mm x 50 mm very small scintillators
 - ← making 10mm x10mm granularity by alternately changing direction of Sci. with 90° into every layer.
- Readout by WLS fiber to get uniformity in 50 mm.
- With **MPPC** (Multi Pixel Photon Counter) for each scintillator

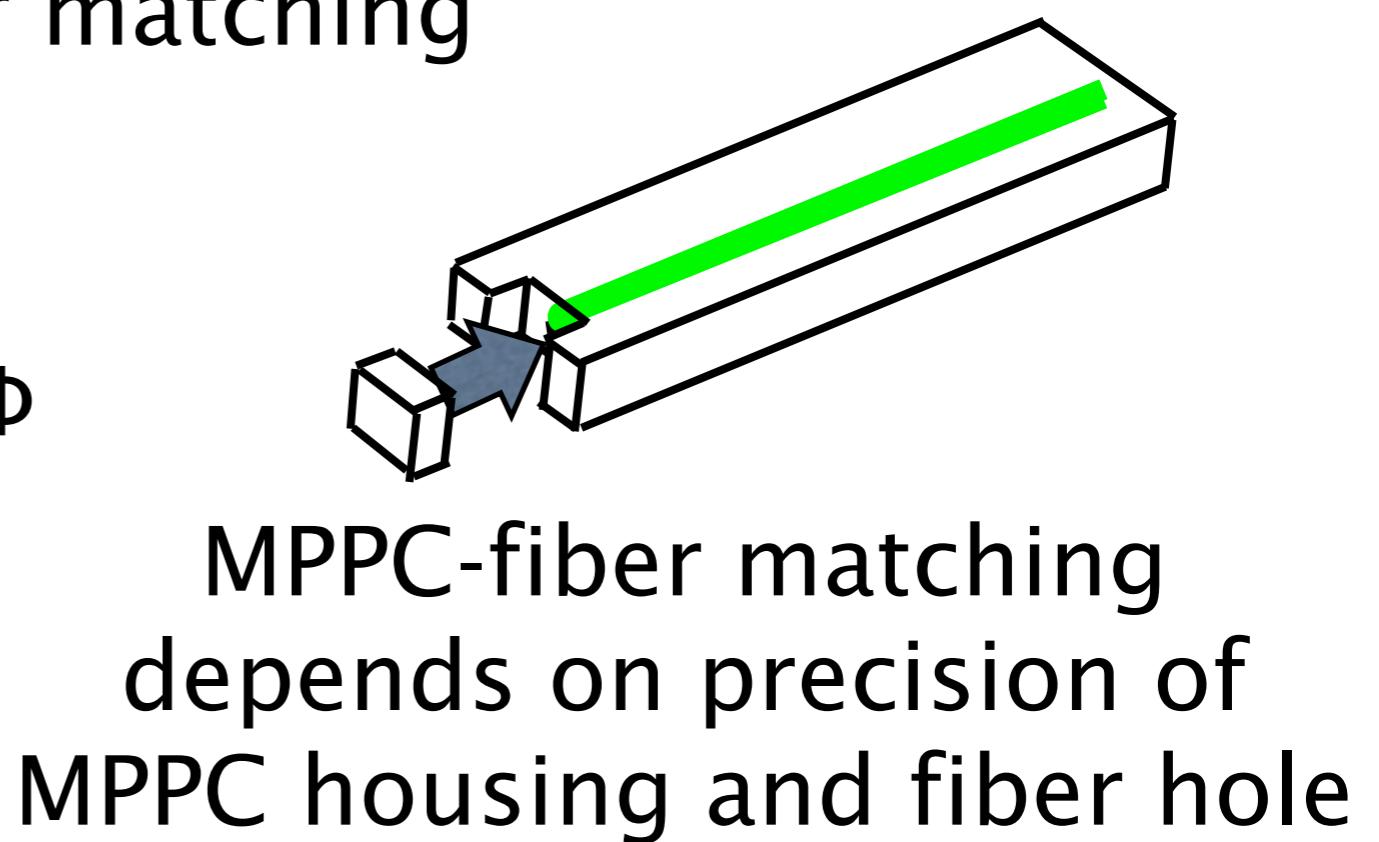
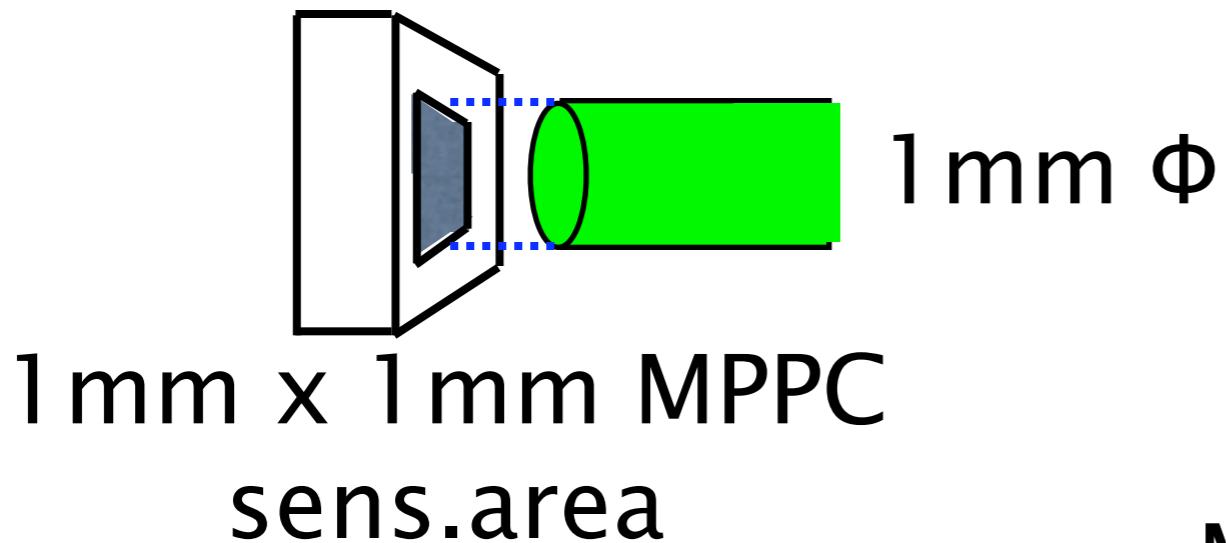
Such detector becomes..



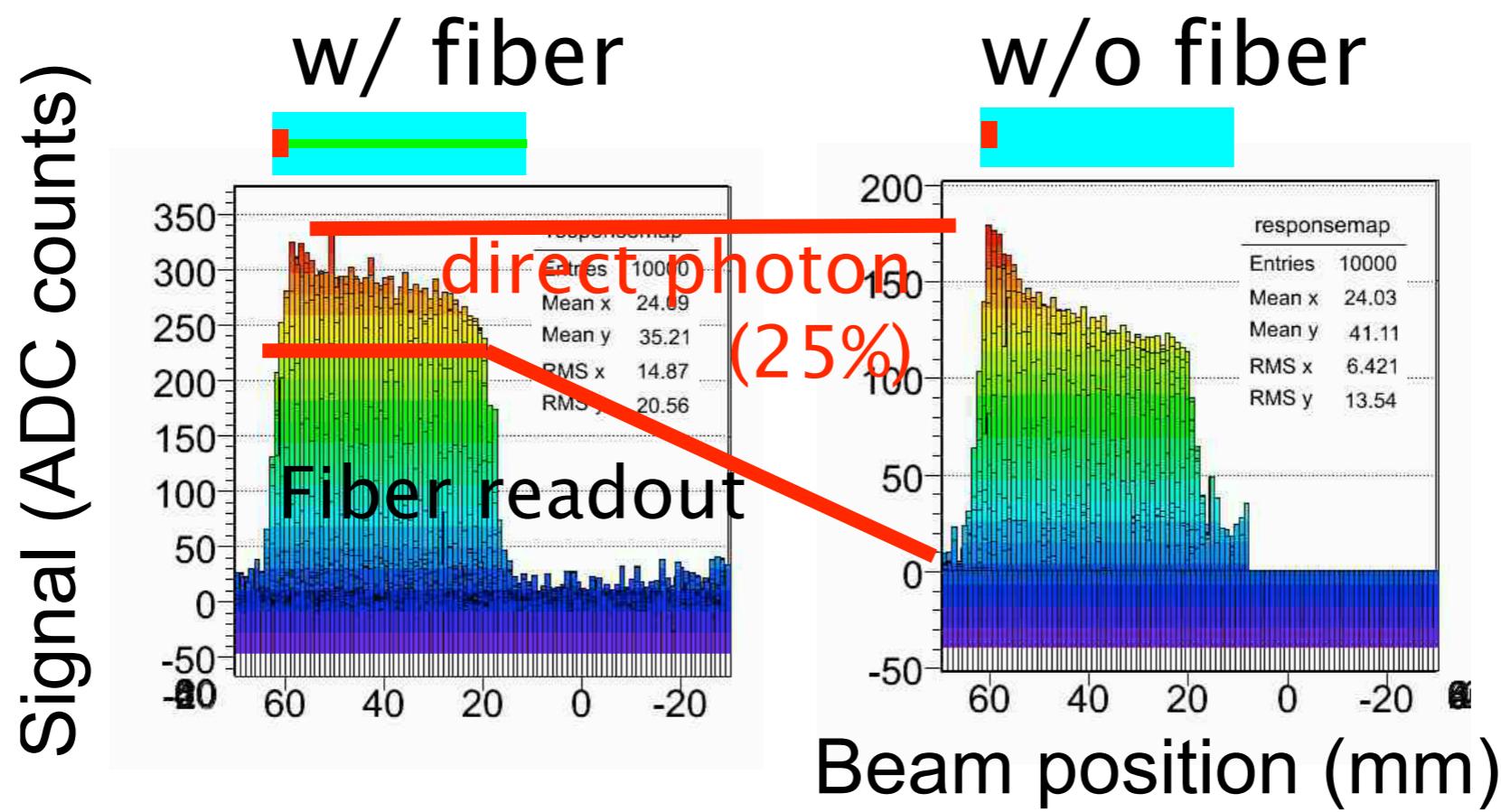
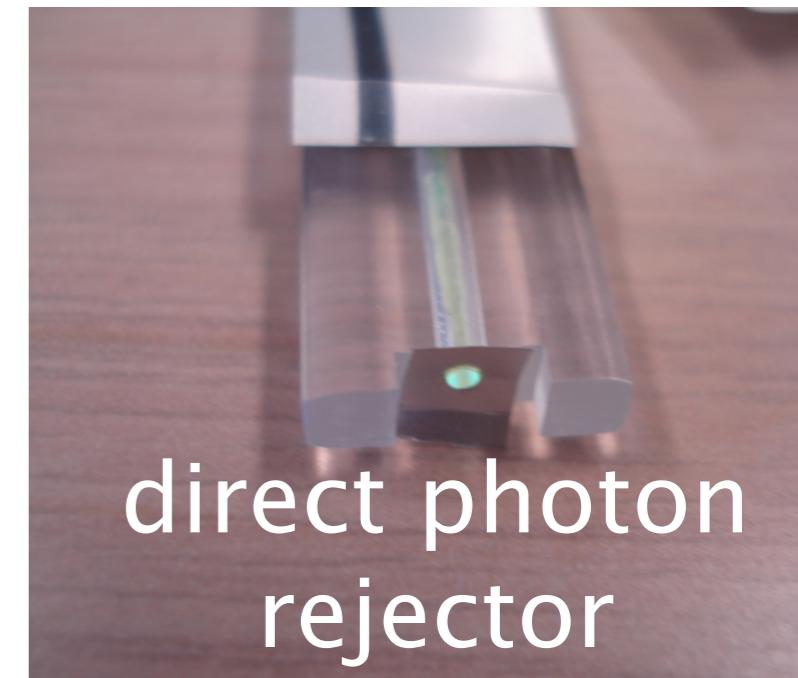
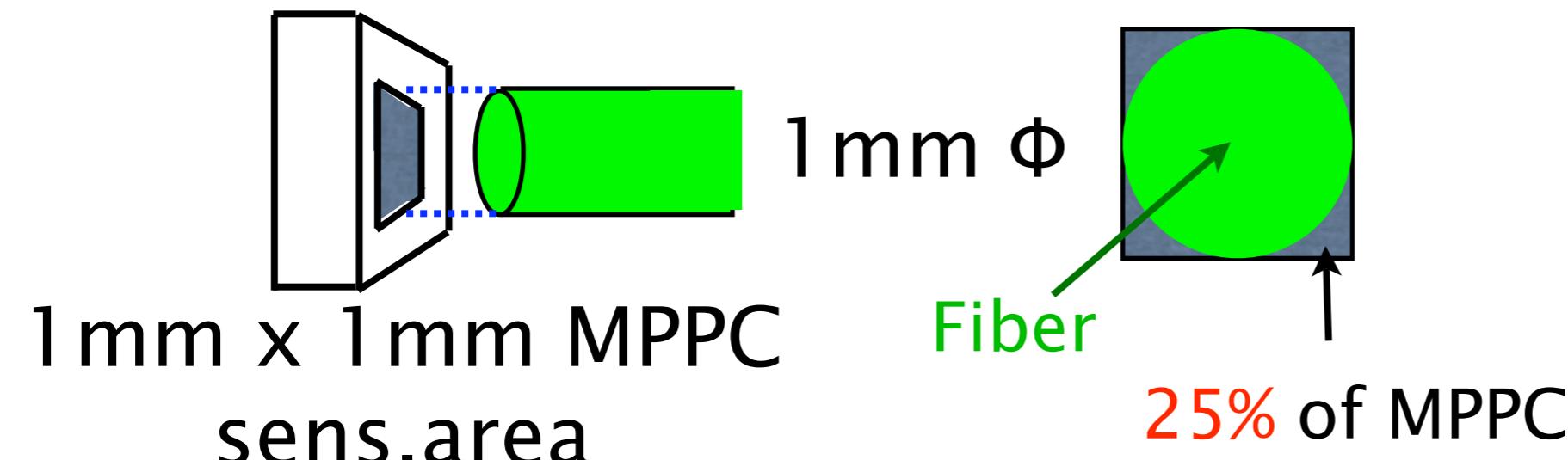
Such sci.strips should be...

Scintillator strips

- enough attenuation length of photon transportation.
- precise molding technique
- to keep MPPC-fiber matching



Direct photon rejector



MPPC (Hamamatsu)

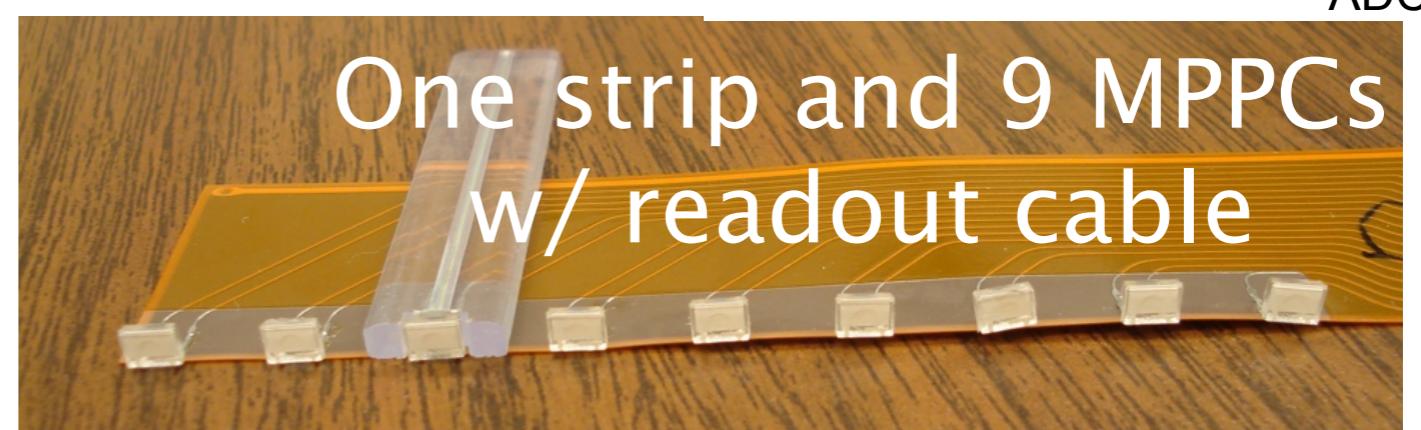
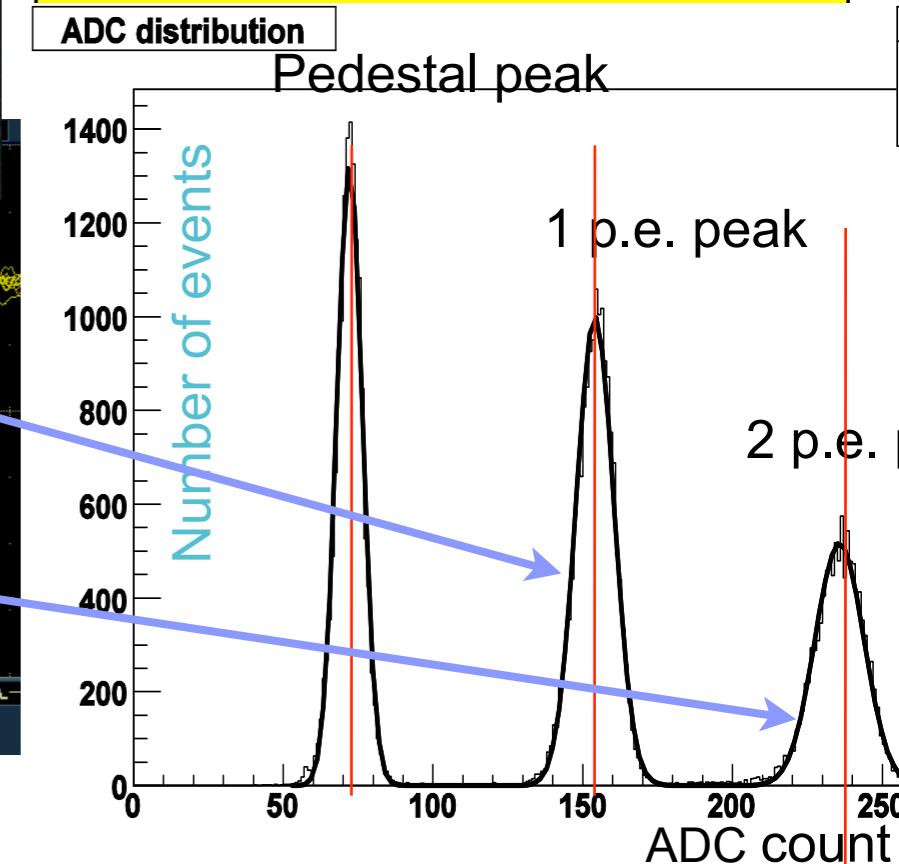
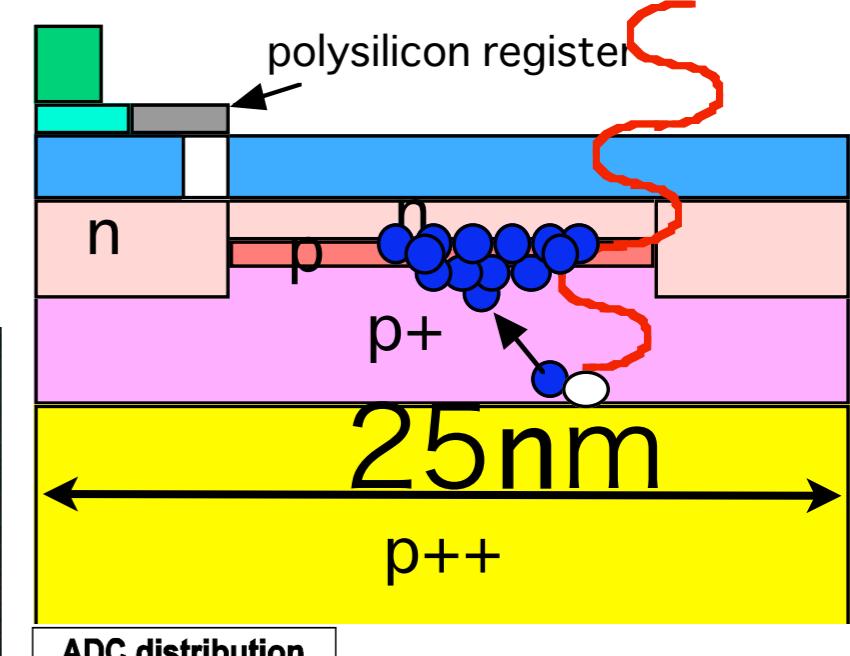
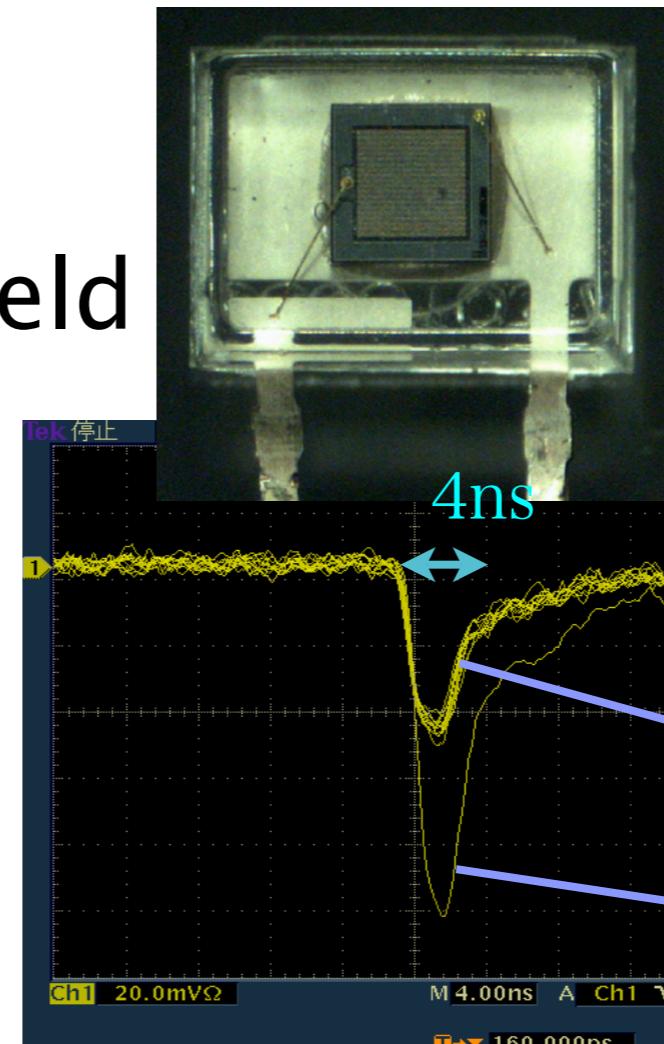
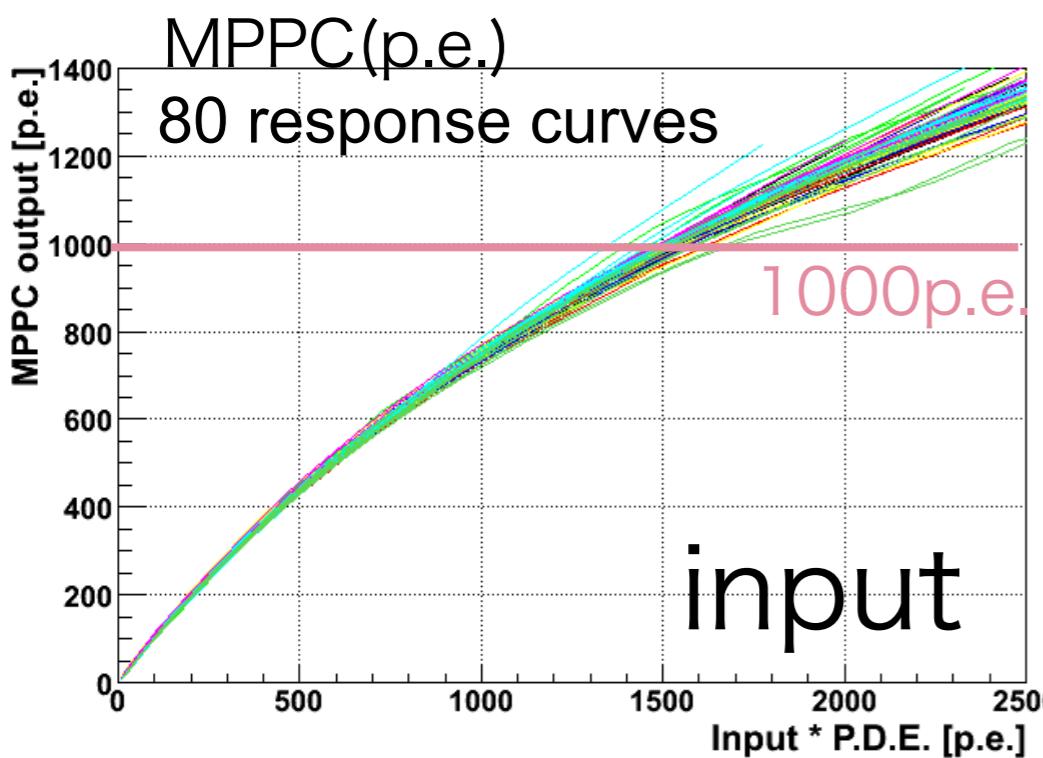
40x40=1600pixels

Advantages

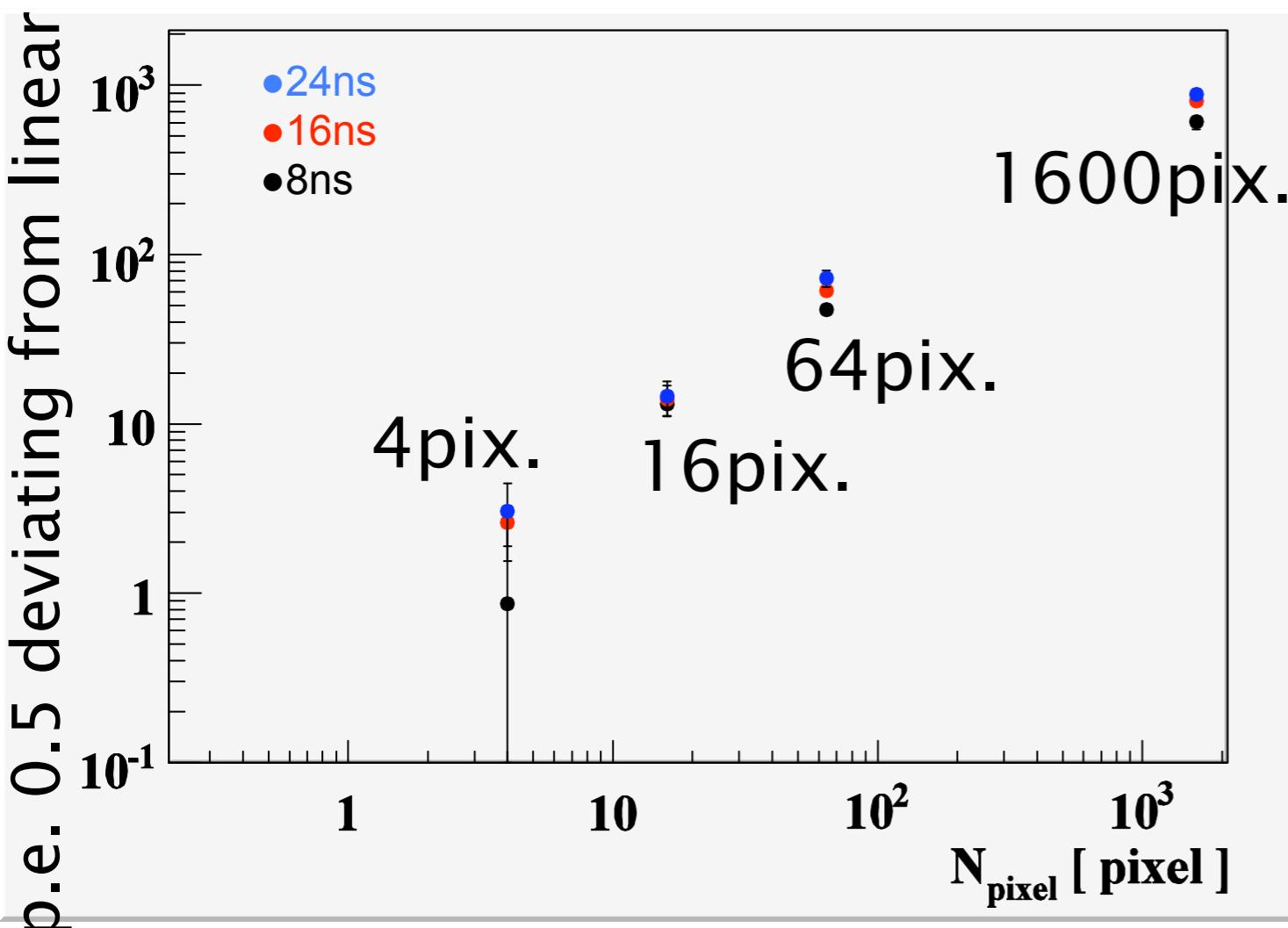
- self calibration
- tolerance to magnet field
- not expensive
- small

Limitations

- saturation



Linearity dep.on the # of pixel

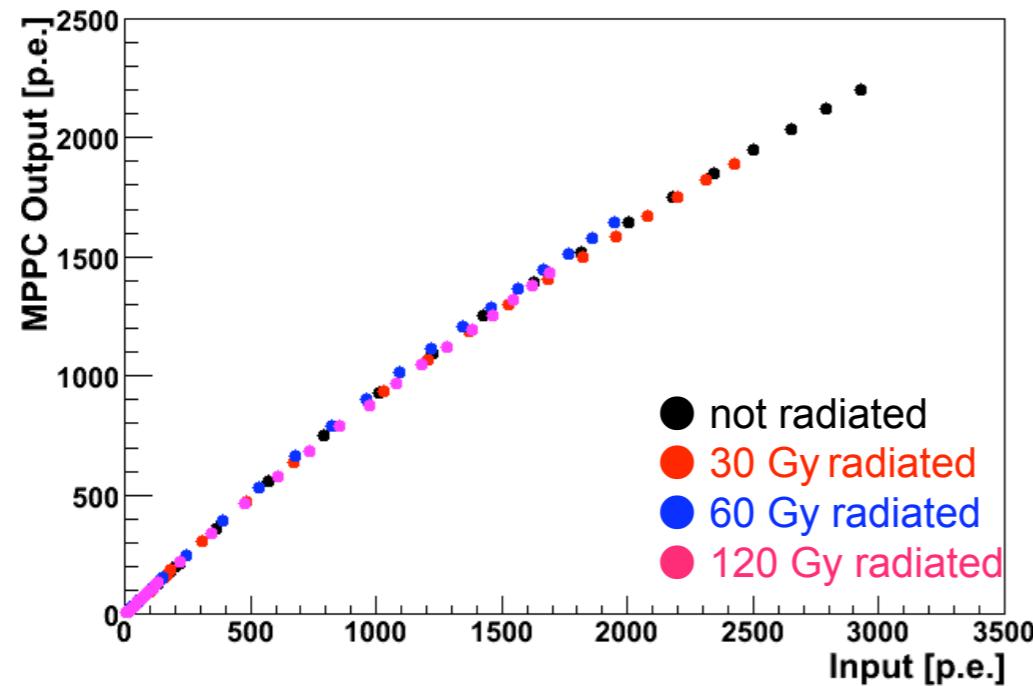


- Linear region becomes larger as the number of pixels increases.
- pulse width also increases linearity.

Y.Takahashi *et al*, U-Tukuba investigated linearity depend on the number of pixel and pulse width.

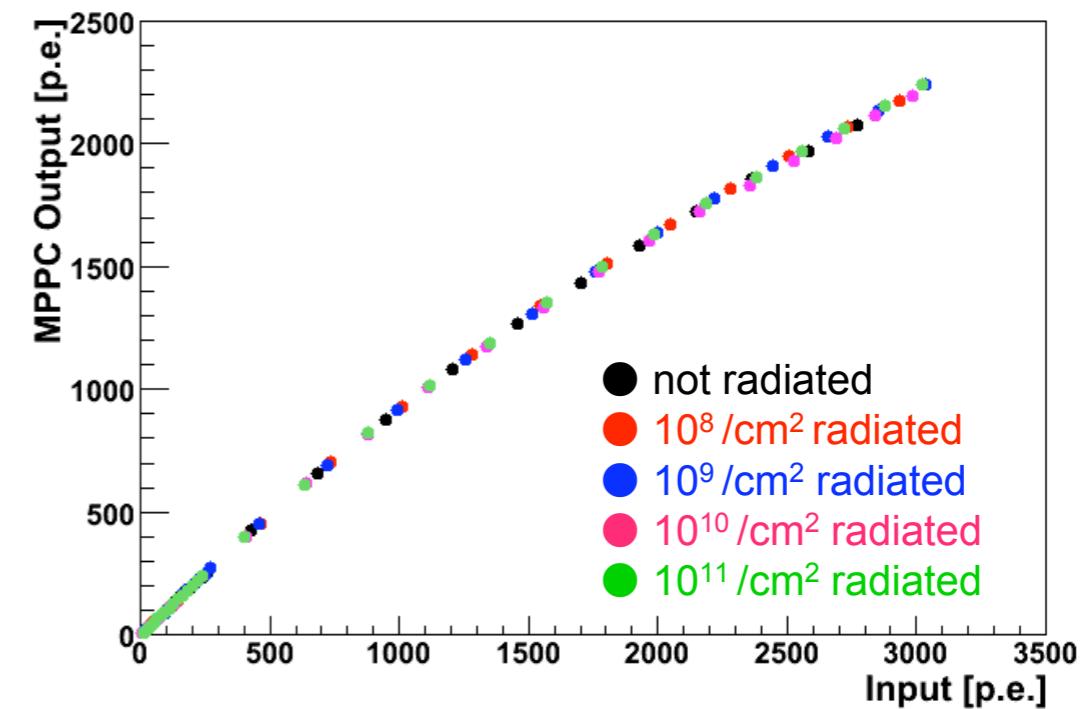
Radiation Tolerance

■ Gamma-ray(Response Curve)



The response curves have not changed by gamma-ray radiation.

■ Neutron(Response Curve)



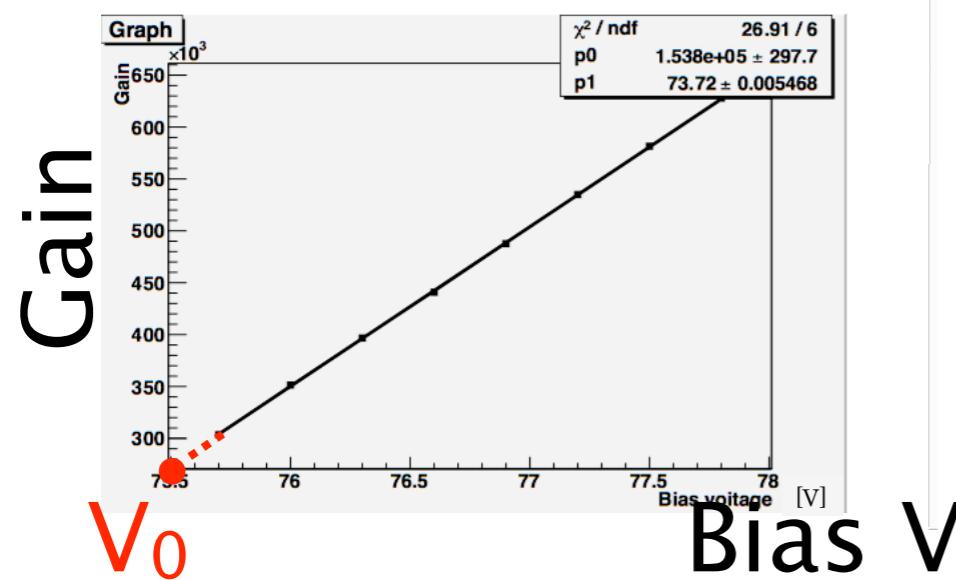
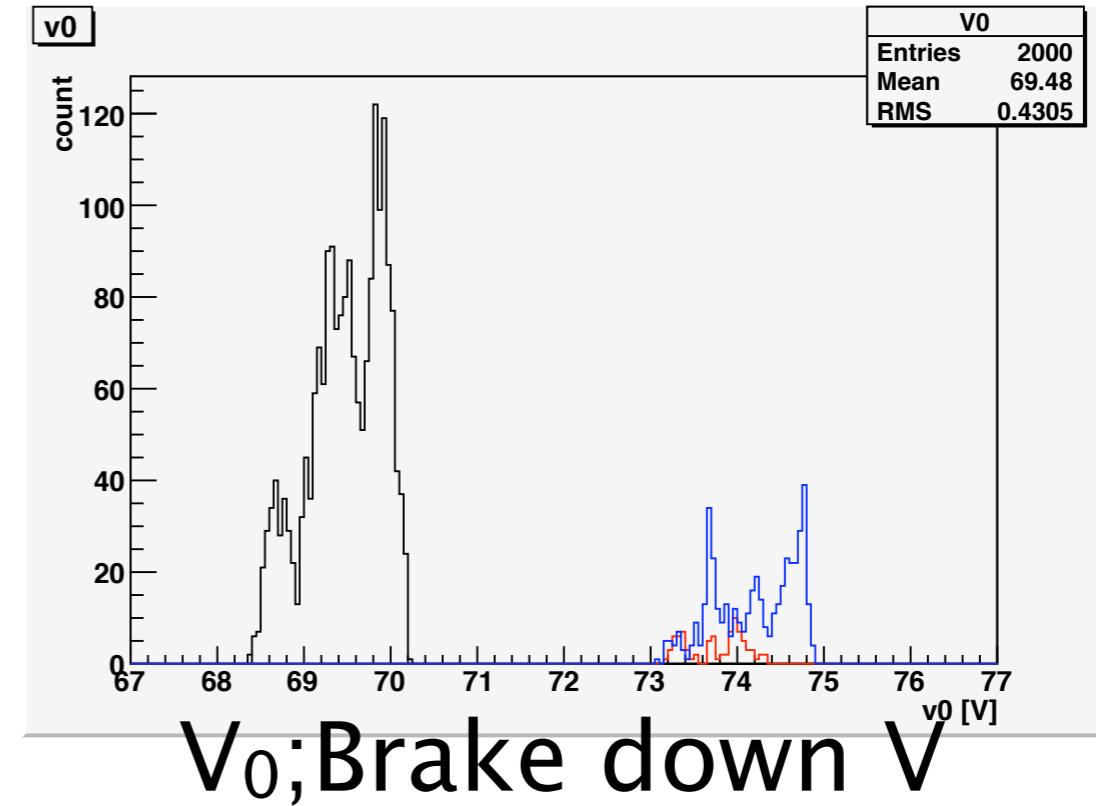
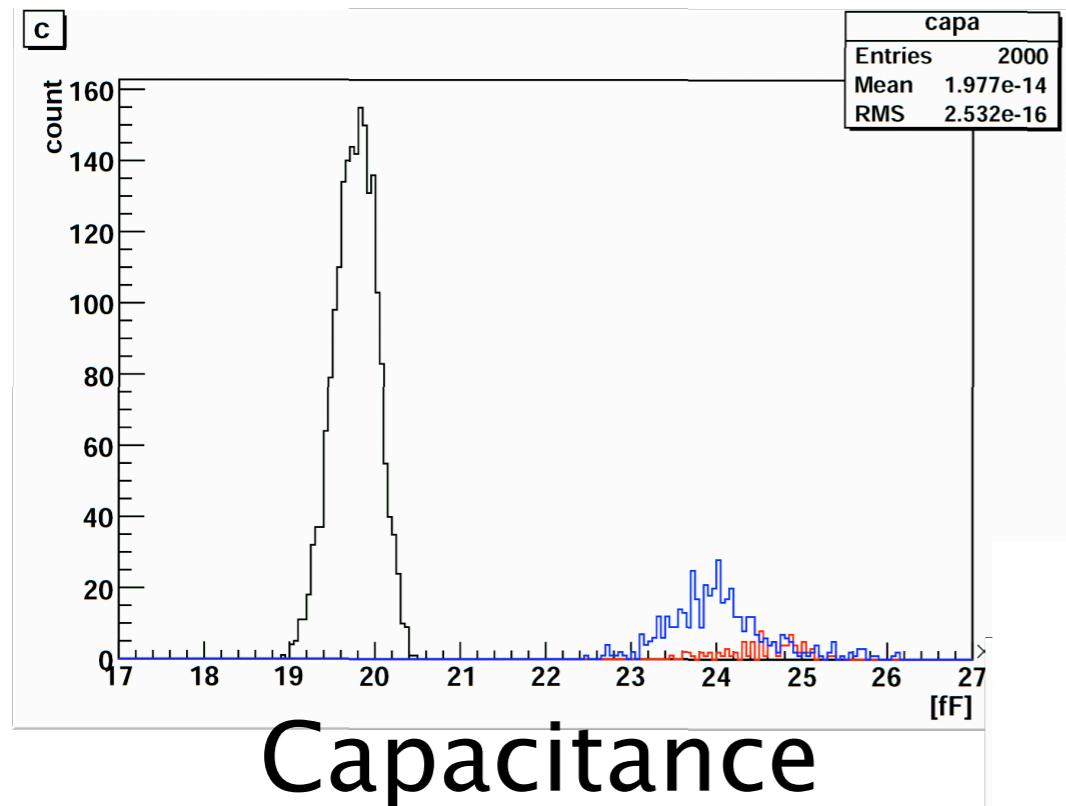
The response curves have not changed by neutron radiation.

T.Ikuno *et al*, U-Tukuba,

- Leakage current and noise rate increase (90Gr γ thre.)
- Cross talk and Gain do not have significant changes.
- Response curves do not change.

V_0 and Gain

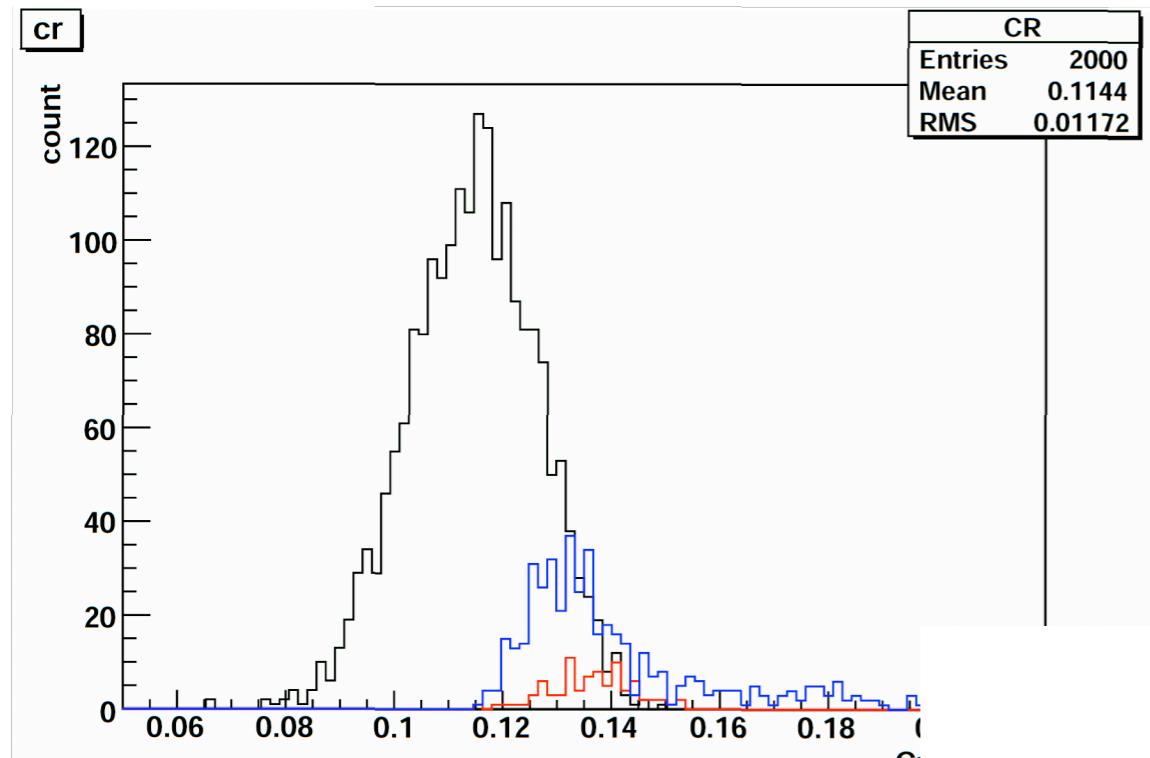
- Characters of 2000 MPPC were measured



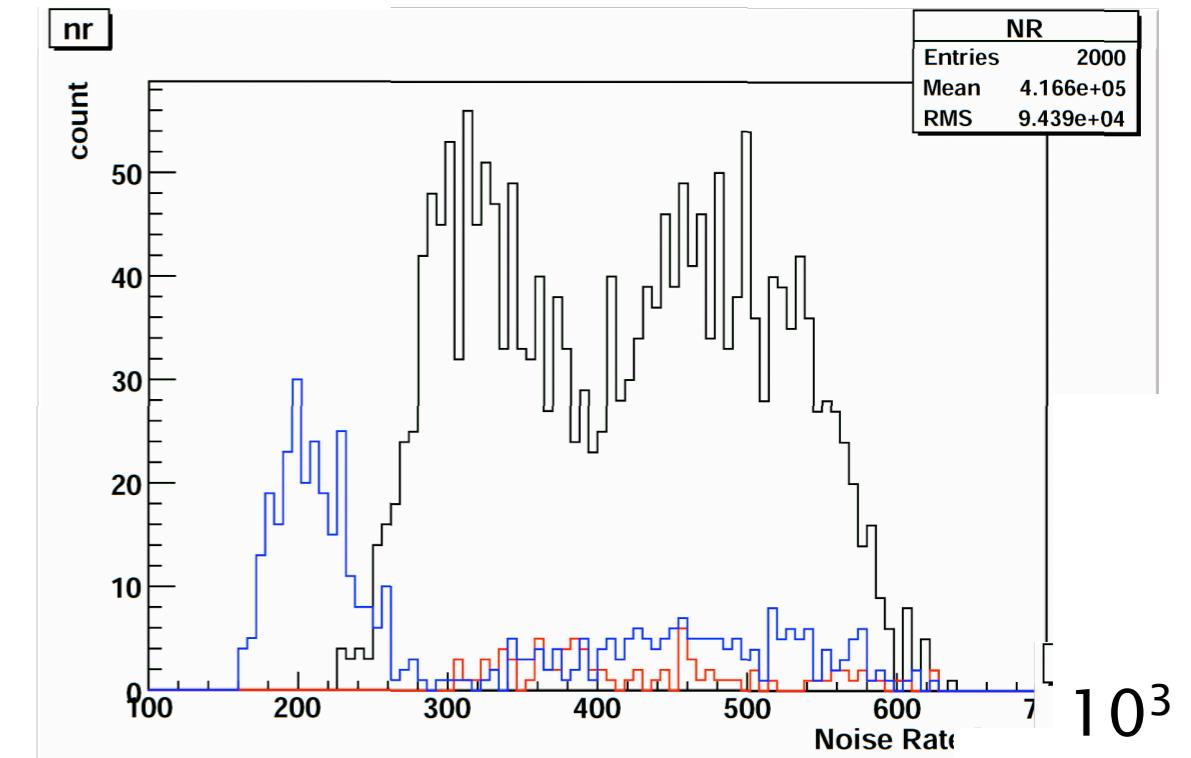
$$G = \frac{C}{e} (V_{\text{bias}} - V_0)$$

5V difference in V_0 is capable for our system

Cross talk and noise rate for 2000 MPPCs at $\Delta V = 3$ V



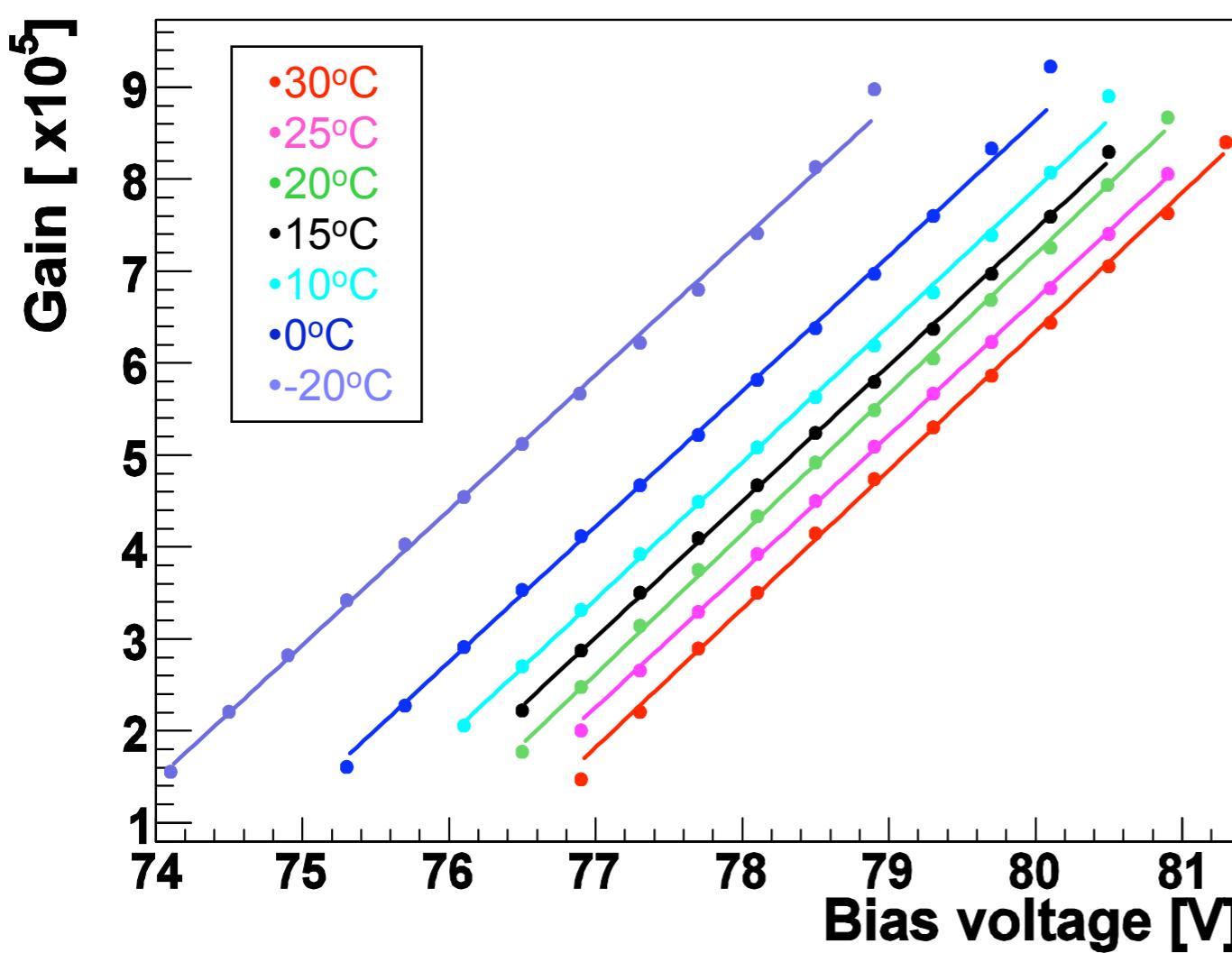
Cross talk



Noise rate

- cross talk and noise are enough small

Temperature dependence of Gain is not small



$$\frac{\Delta V_0}{\Delta T} = (5.60 \pm 0.1)(mV/K)$$

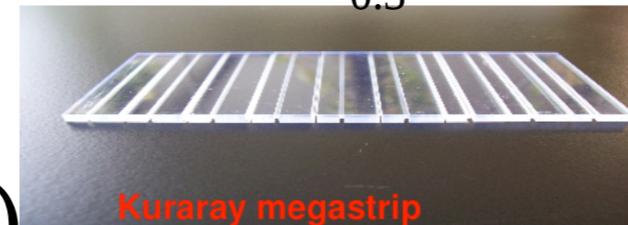
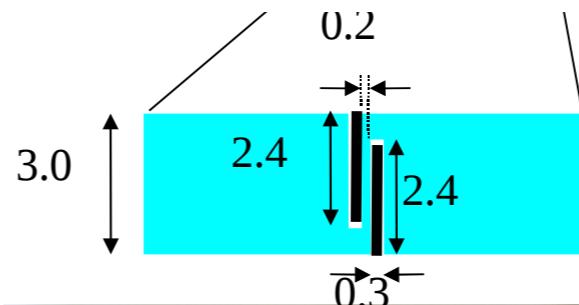
- monitoring and correction are required in our experiment.

First step; 1-6 GeV electron beam test @DESY

Comparing 3 types strips:

Kuraray (Megastrip)

1. WLSF readout

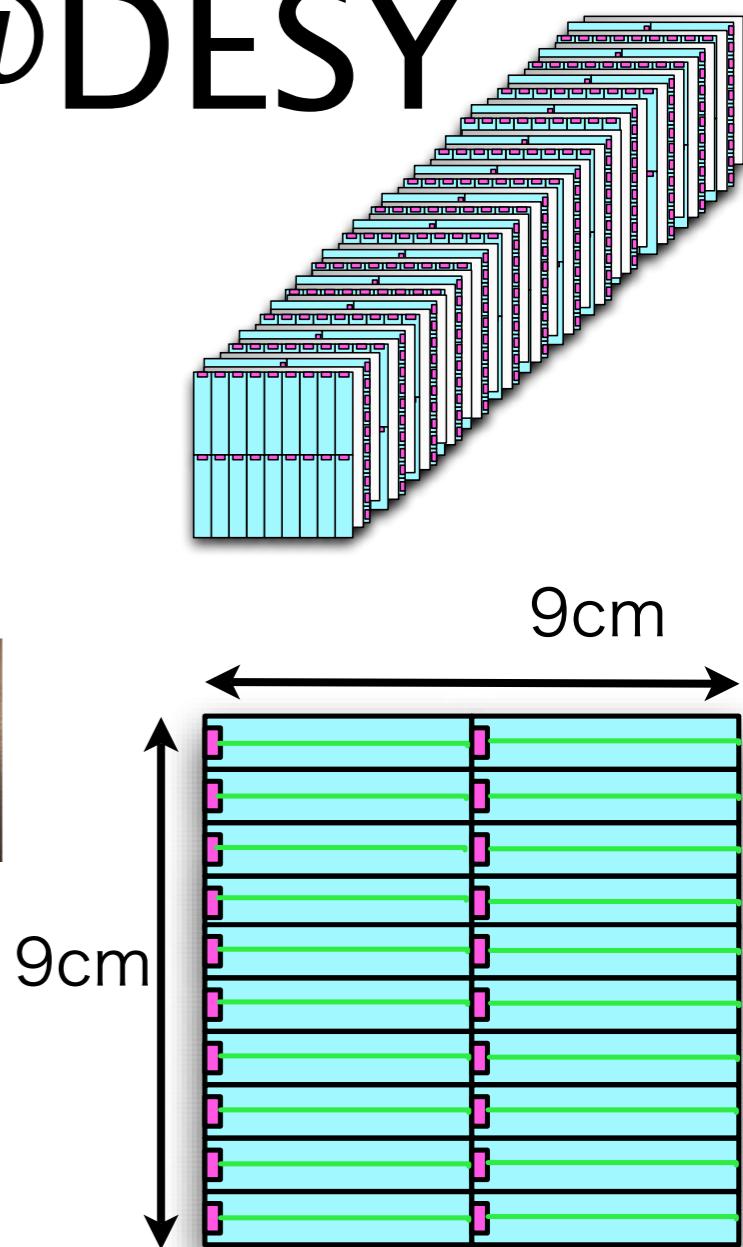
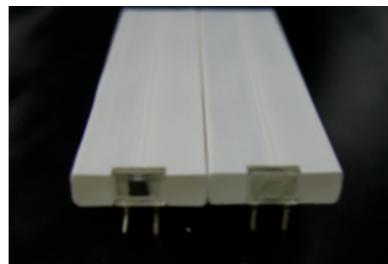


Misung Chemical Co.(Korea)

Kyunpook National University

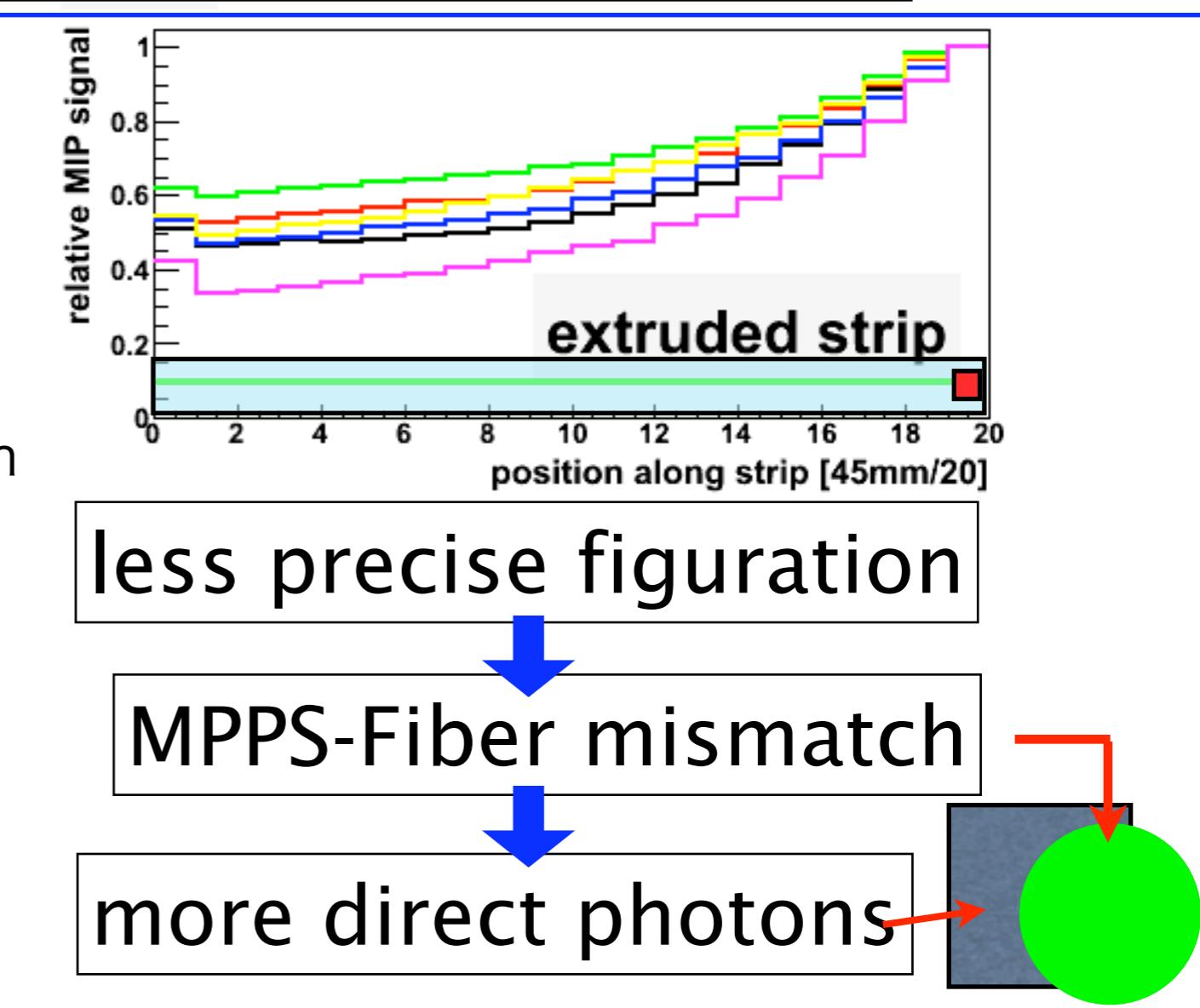
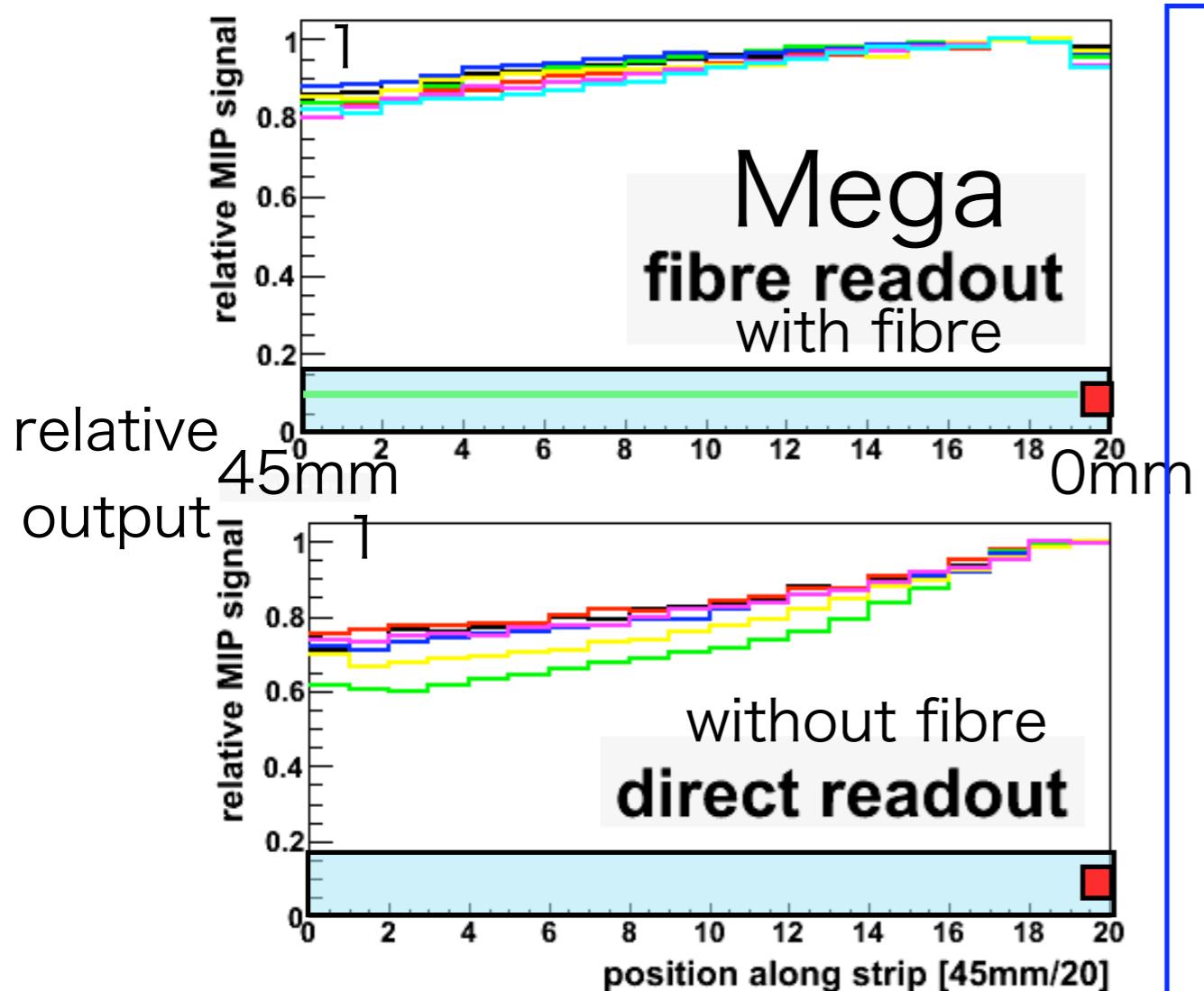
3. individual extruded strips

- co-extruded TiO₂ covering
- WLSF readout.

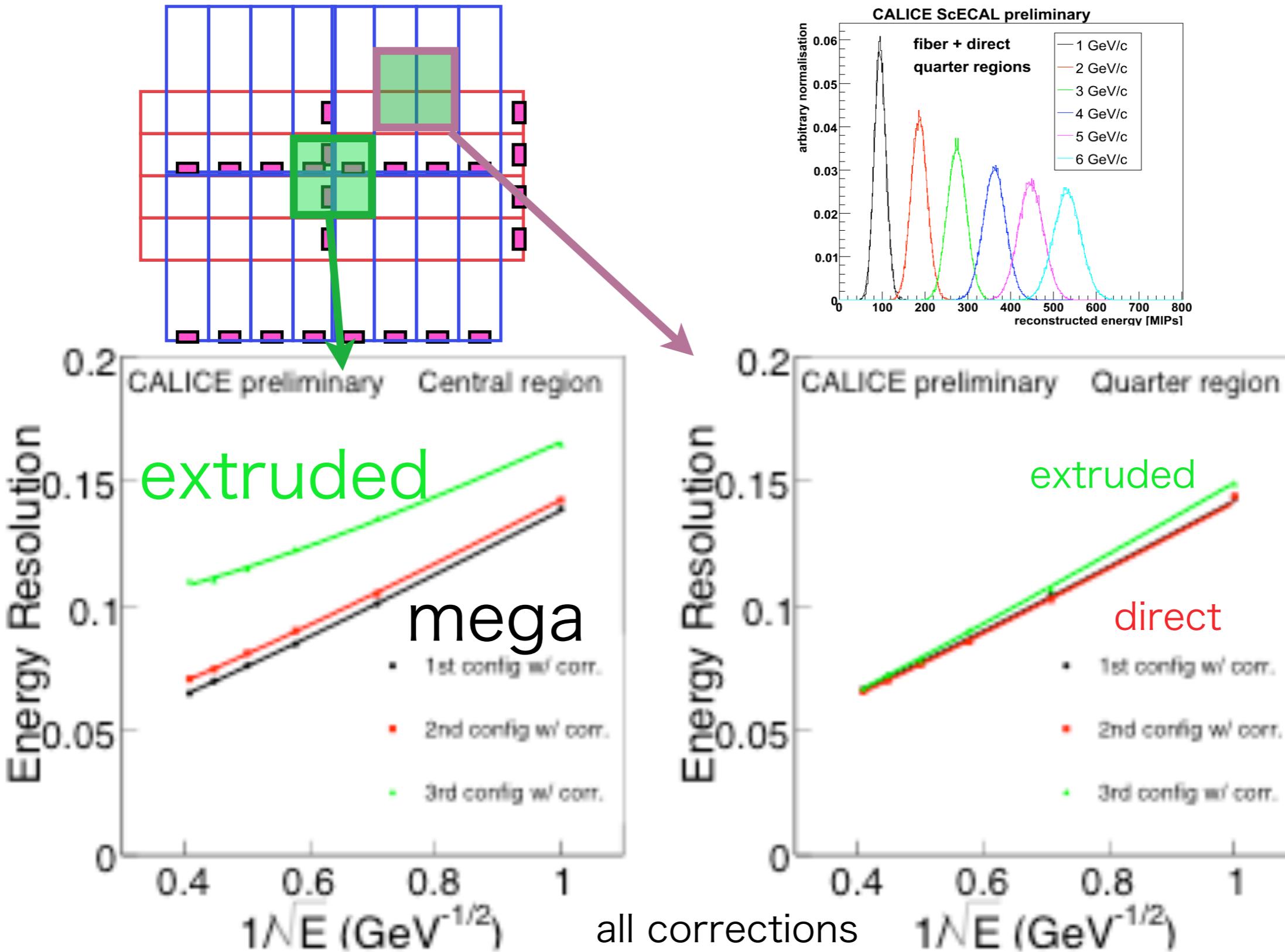


Results of comparison

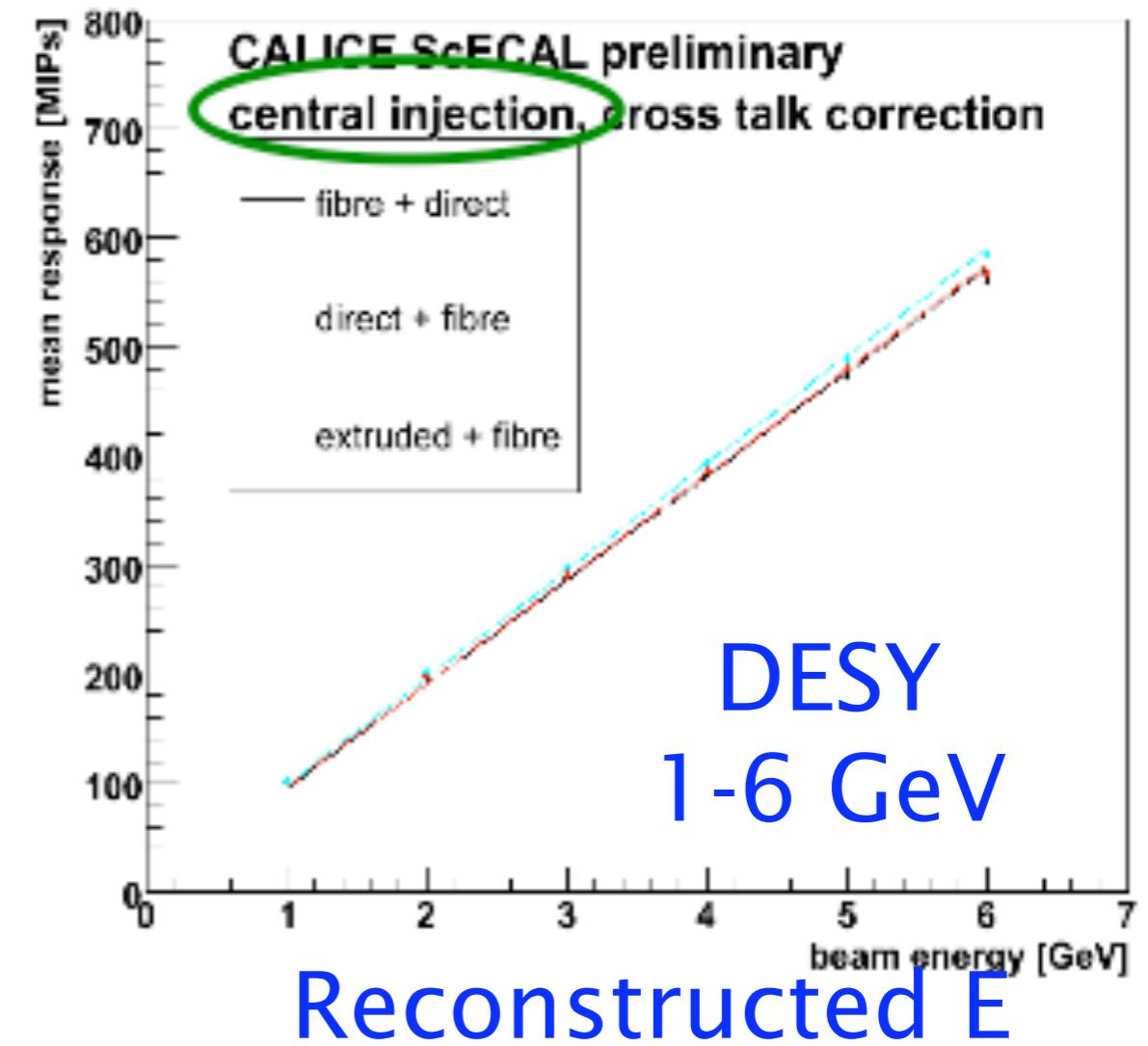
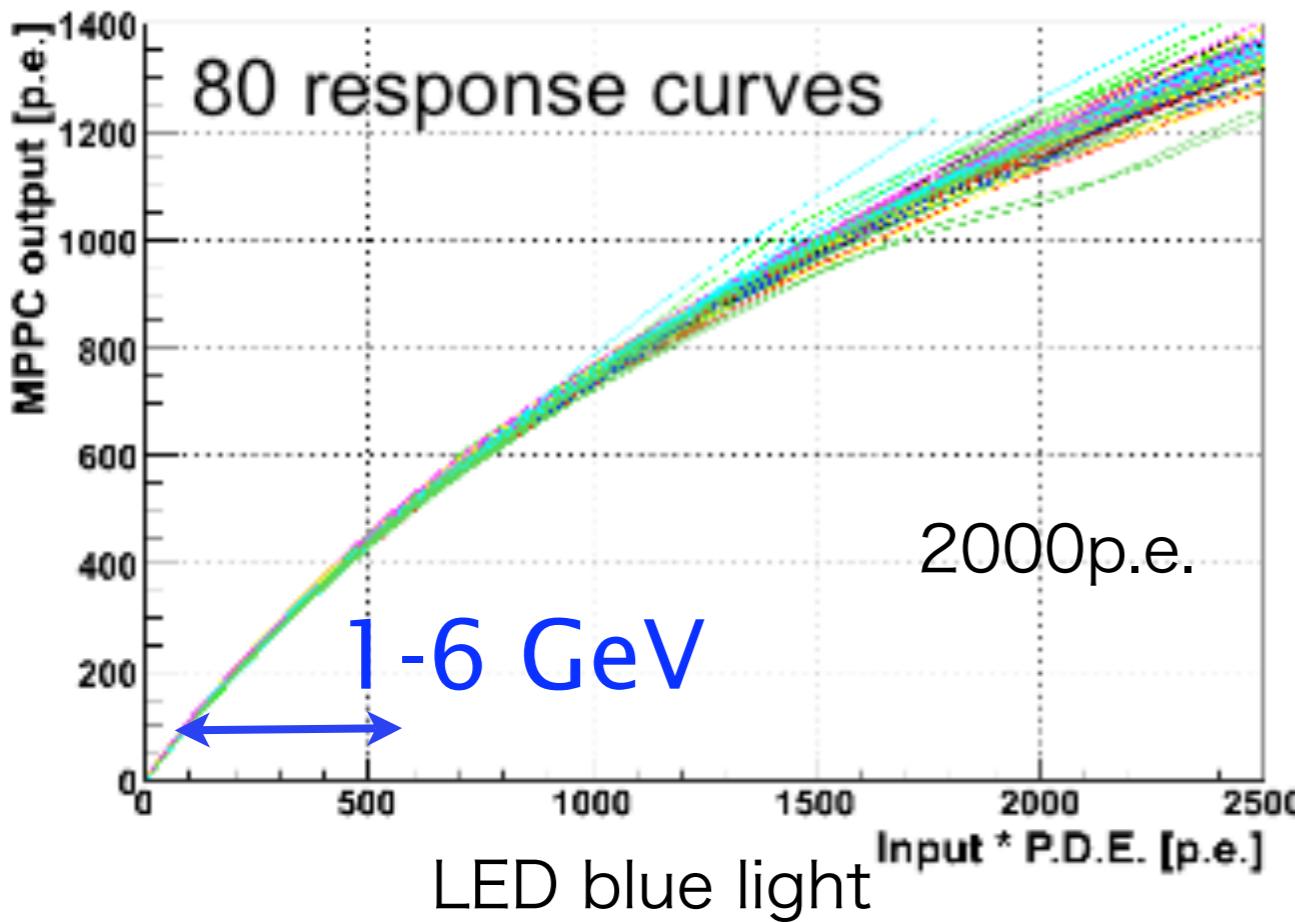
	strip	light X-talk	uniformity
Kuraray	Mega	✗ 10%	good
	direct r/o		▲
KNU	extruded	good	need study



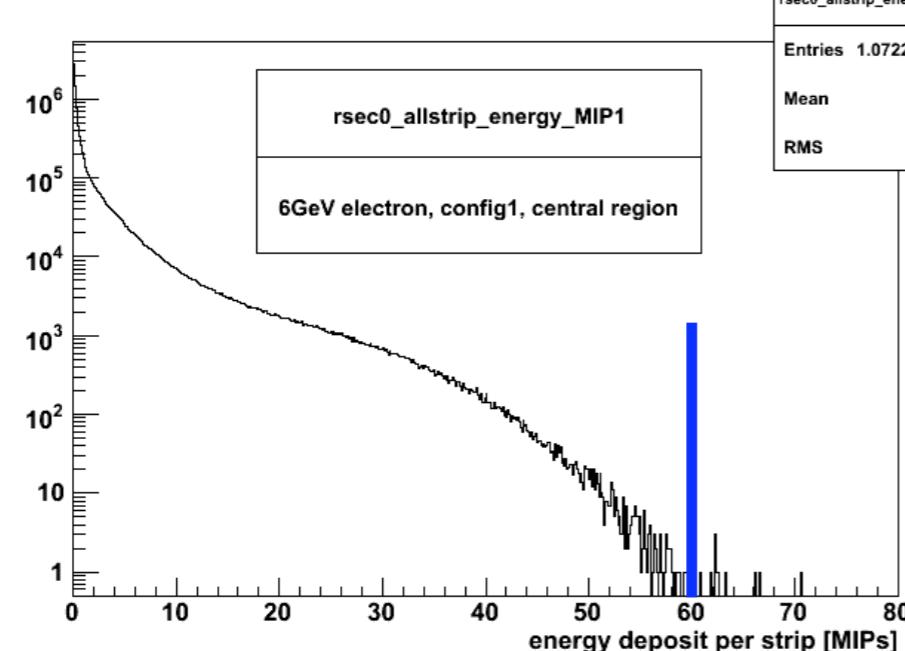
Effect of non-uniformity on the energy resolution



MPPC saturation



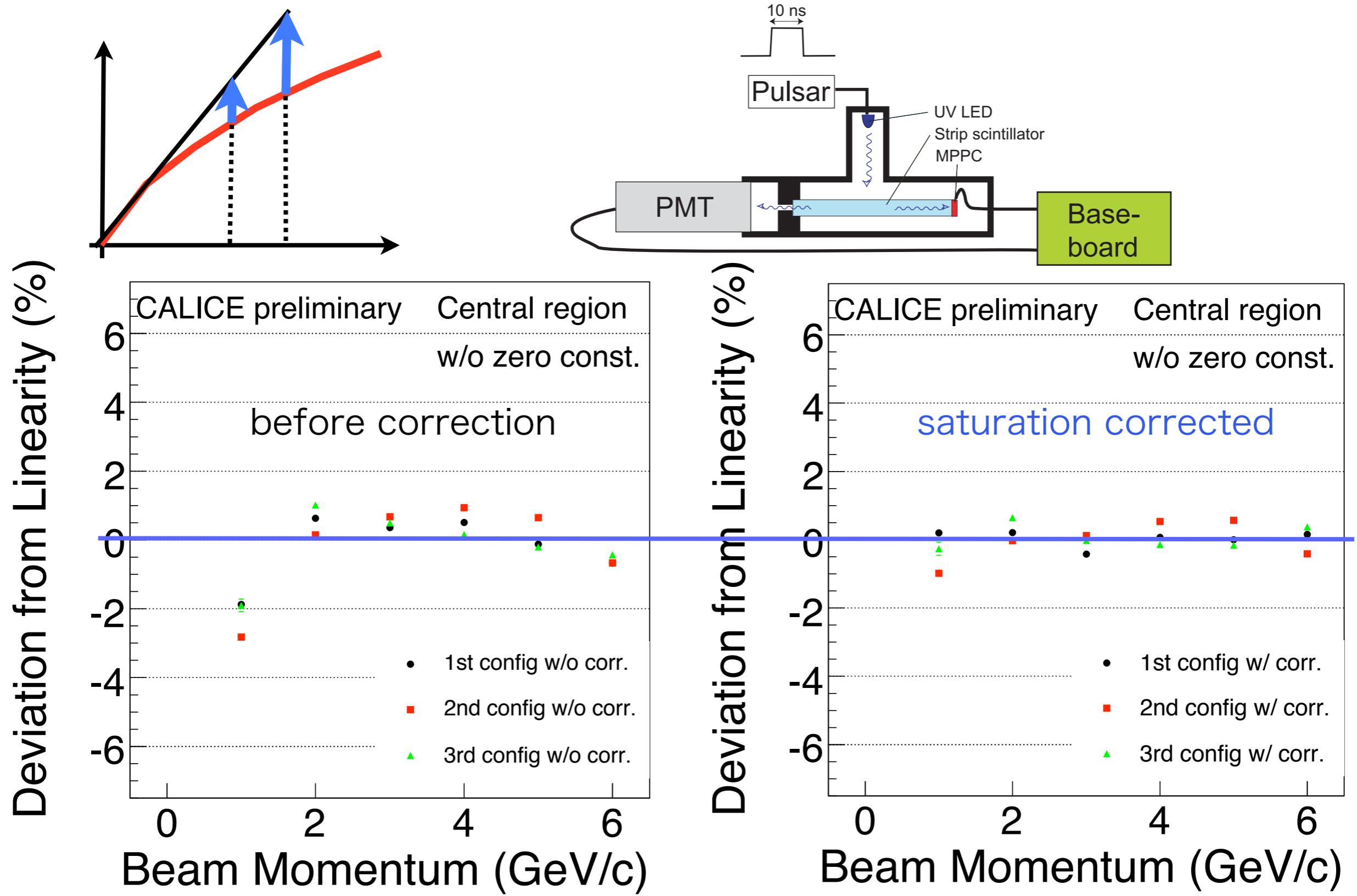
Effect of saturation on the reconstructed energy is very small at least up to 6 GeV



with 6 GeV e, max E in a strip ~ 60MIP<1000 p.e.

linearity

saturation correction improbes linearity

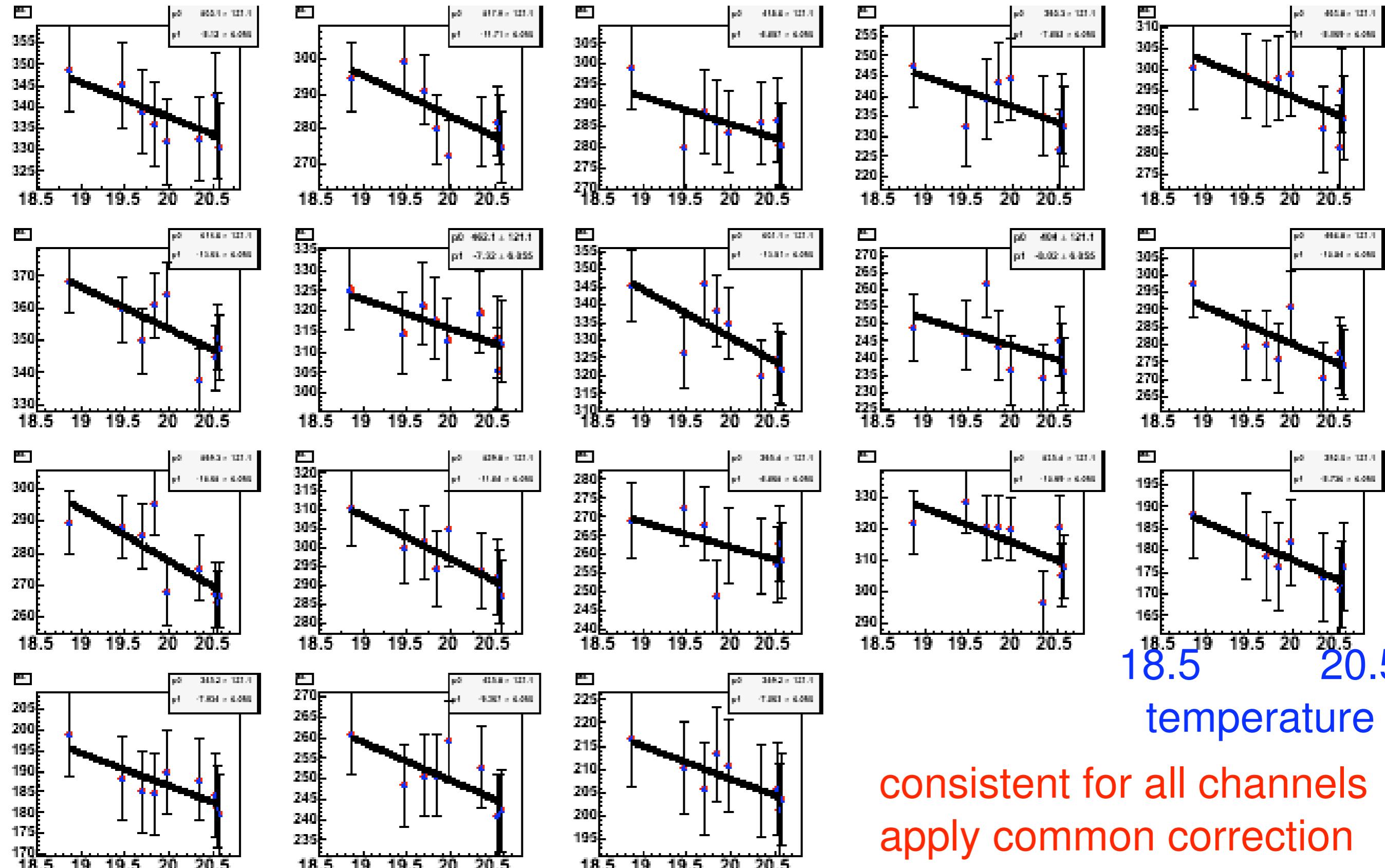


MIP response temperature dependence

MPPC properties change with temperature

a few %/°C

example: 18 strips in one layer



consistent for all channels
apply common correction

Conclusions of e⁺ test beam at DESY

Analysis of DESY test beam data in good shape

In uniform regions, detector works well

The linearity of energy response is good so far
sufficient energy resolution for ILC ECal

$$\sigma/E \sim 14\%/\sqrt{E(\text{GeV})} + 3\%$$

Non-uniformity of extruded strips significantly degraded performance.

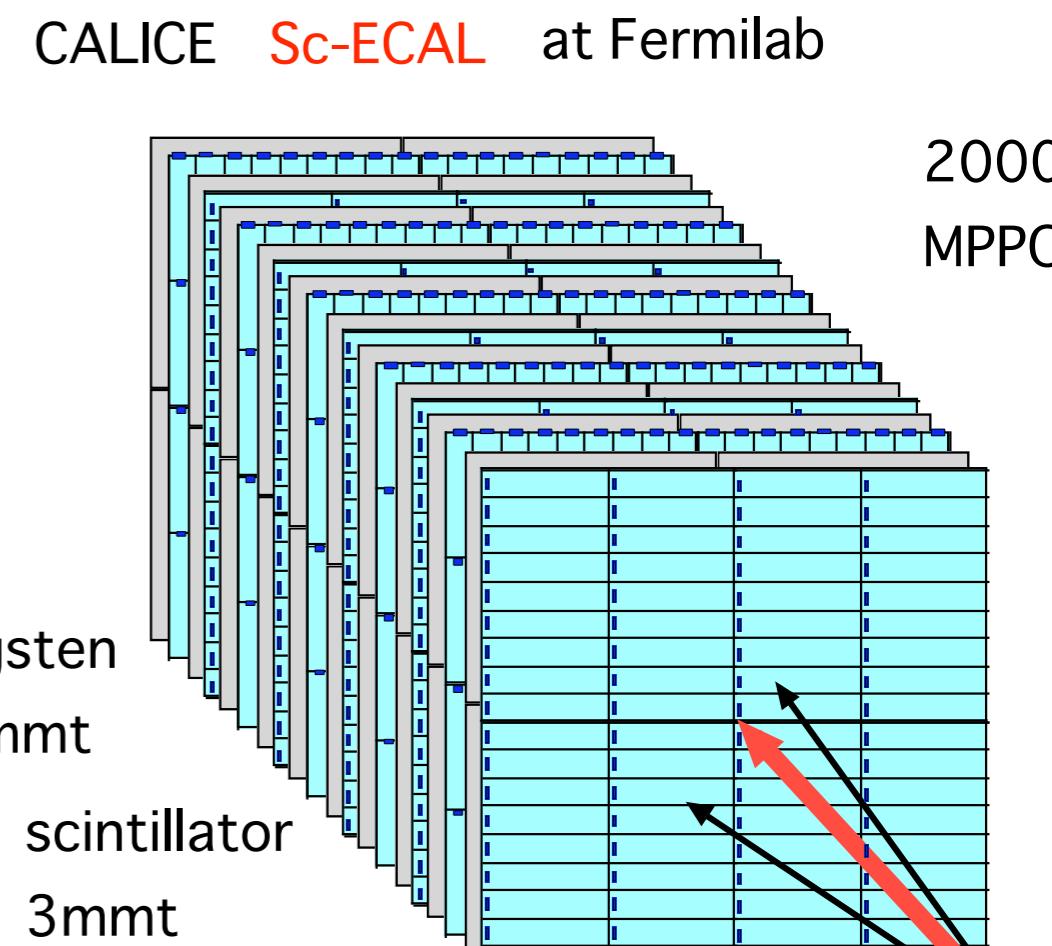
Next step → FNAL Beam test;
Is linearity kept for large energy?
and with other modifications on detector.

1-32 GeV e^- , π^- ,(π^0) Beam test at FNAL (area = DESY x 4)

It's right now running!!

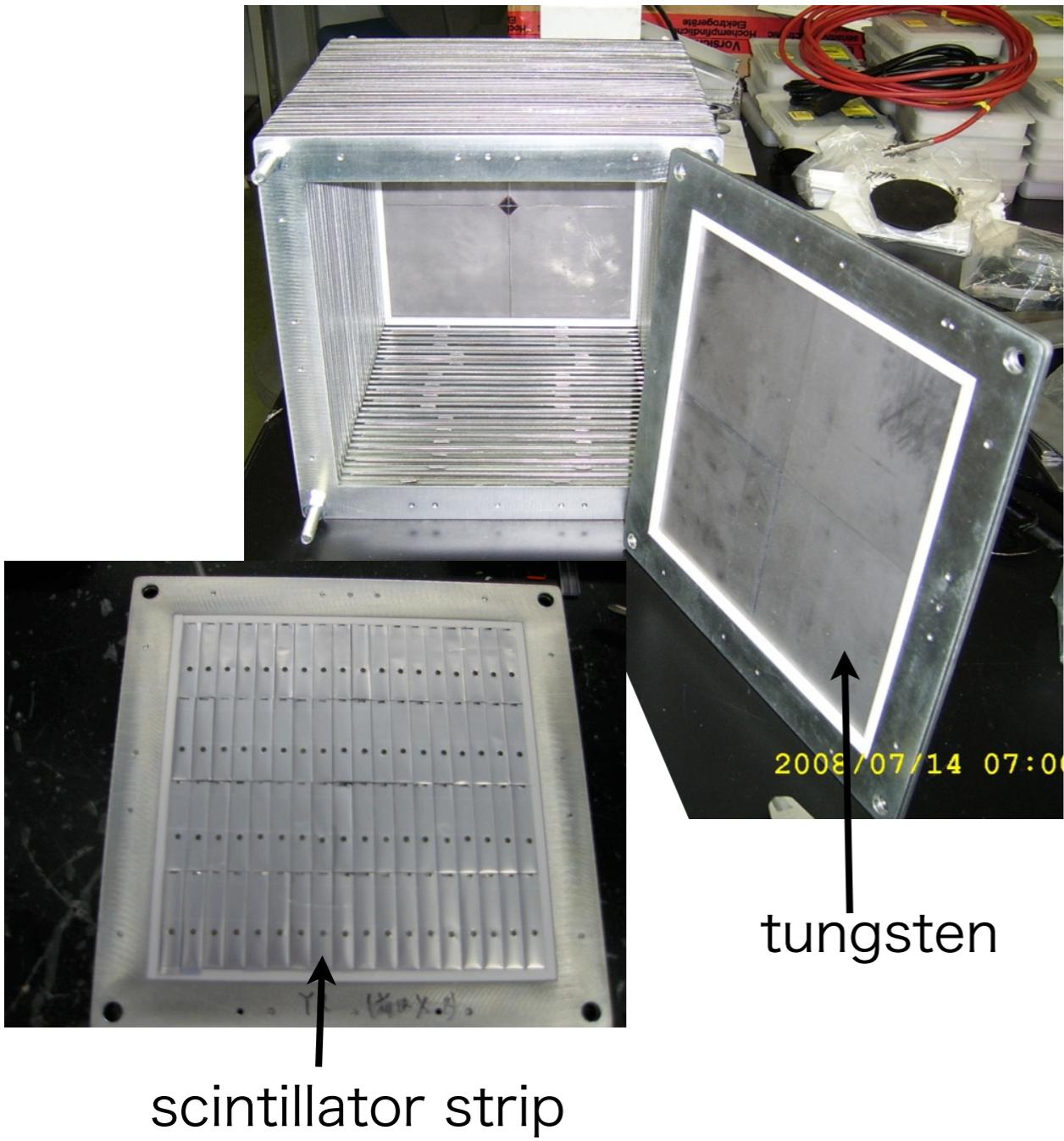
According to studies I showed,
the following is required;

- strips are enclosed in film reflector
- MPPC-Fiber matching (longitudinal) is good
- direct photon rejectors are mounted.

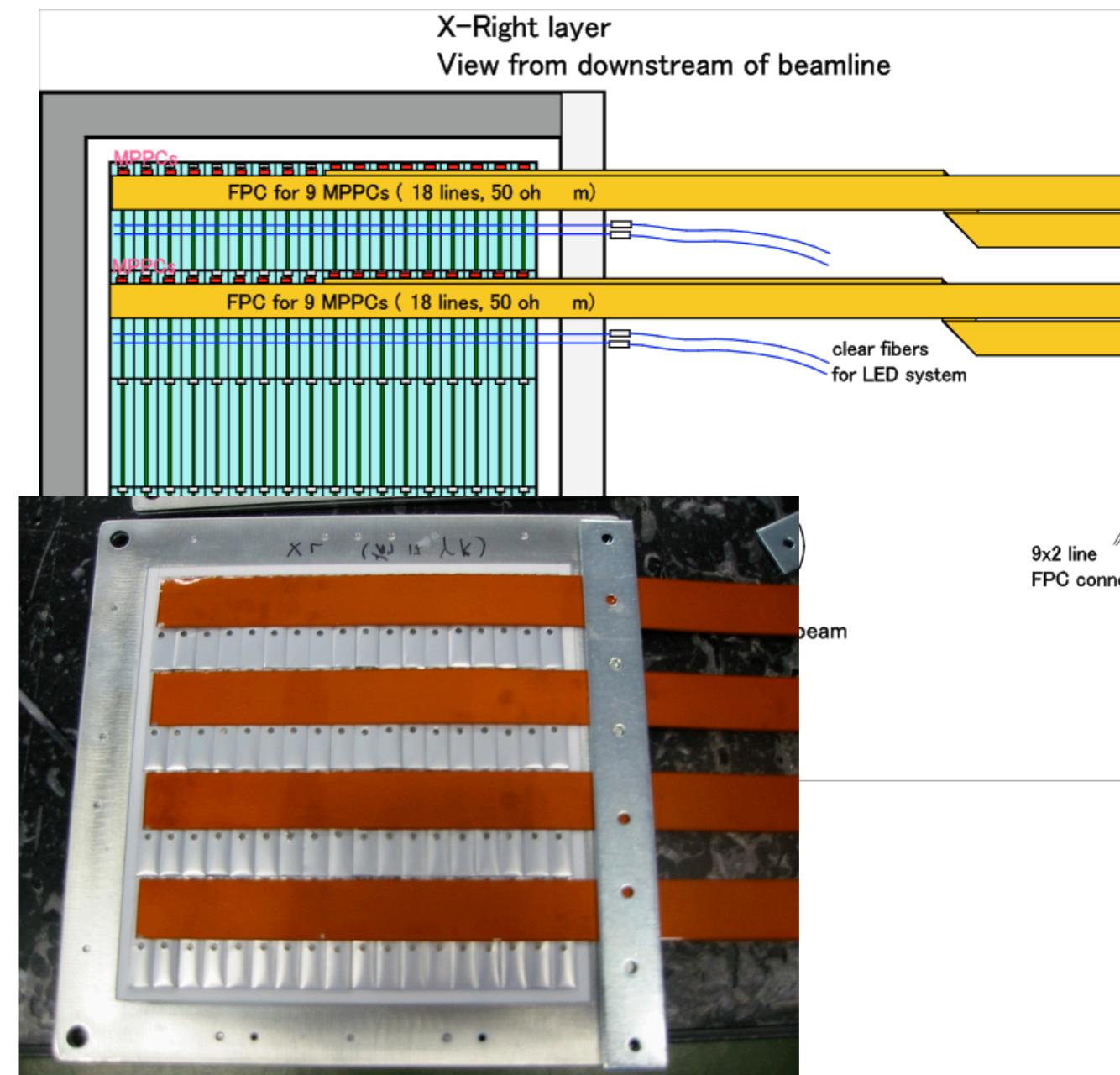


prototype scecal

- structure



W 3.5mm scint. 3mm
18 x 4 lows



Summary of test beam at FNAL

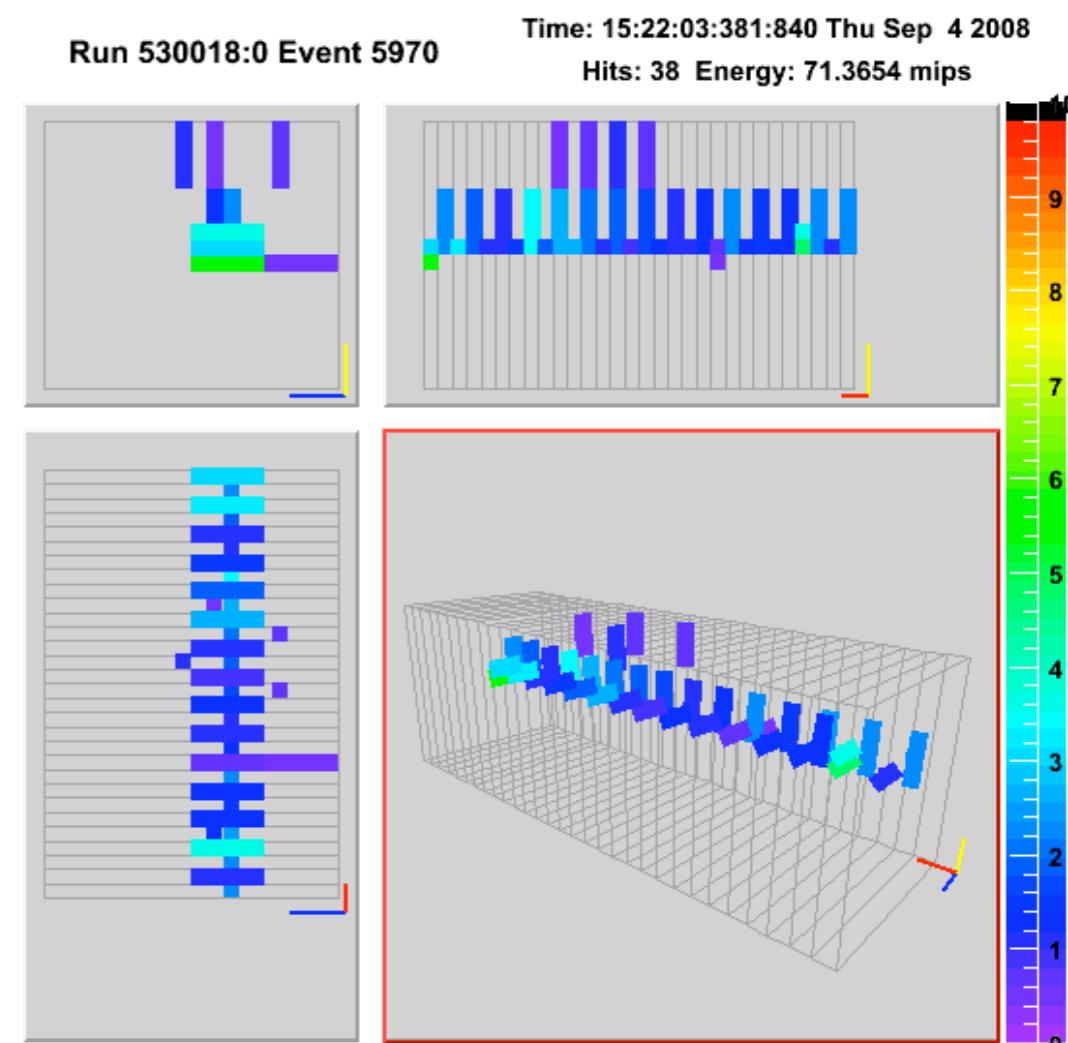
2160 MPPCs were mounted.

for individual MPPC, bias voltages are tuned.

3/4 beam plan have already finished.

Using MIP events, the uniformity looks better than at DESY.

for details, Stop by MT6!

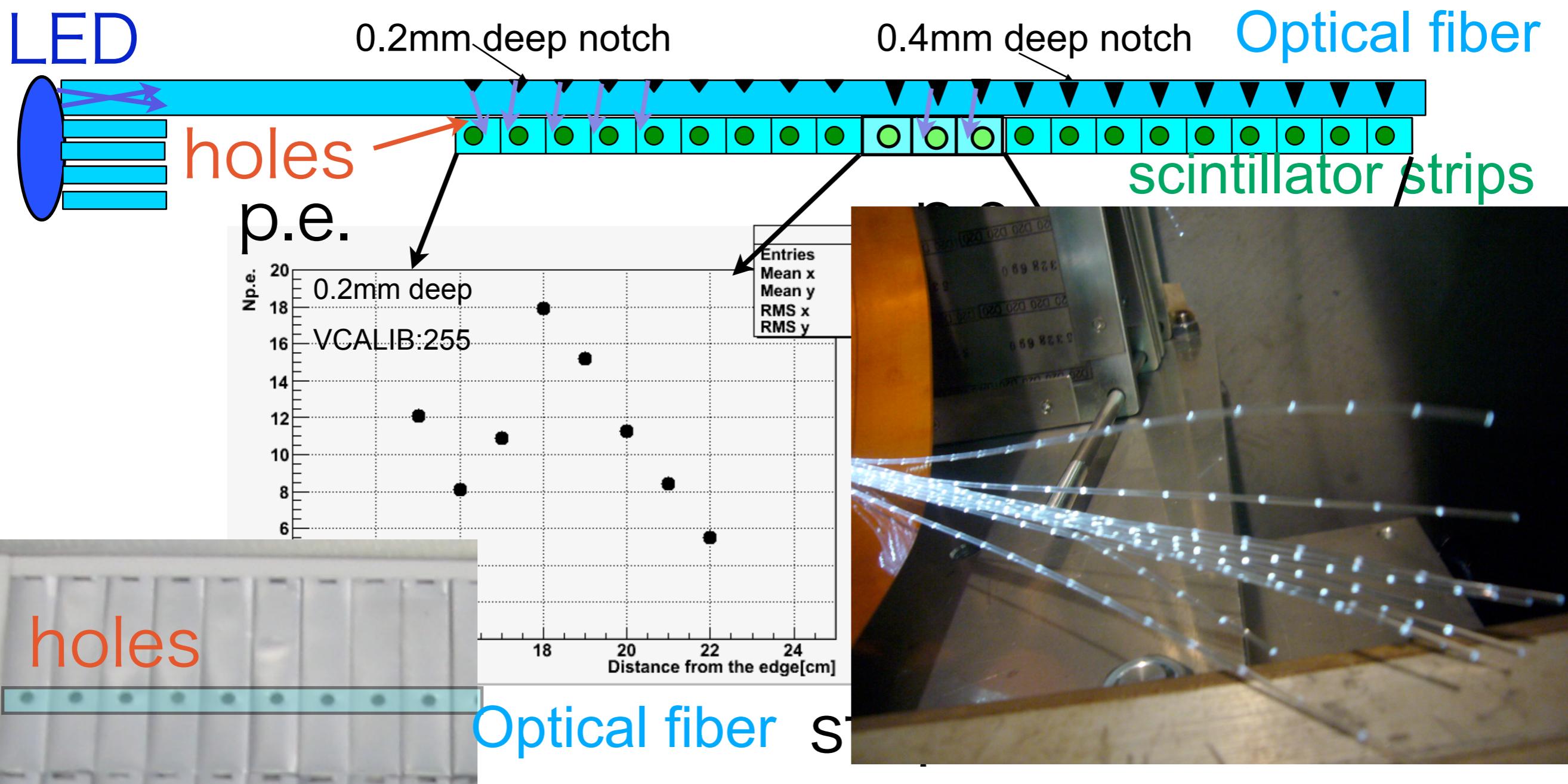


A typical MIP event

Back up

monitoring system

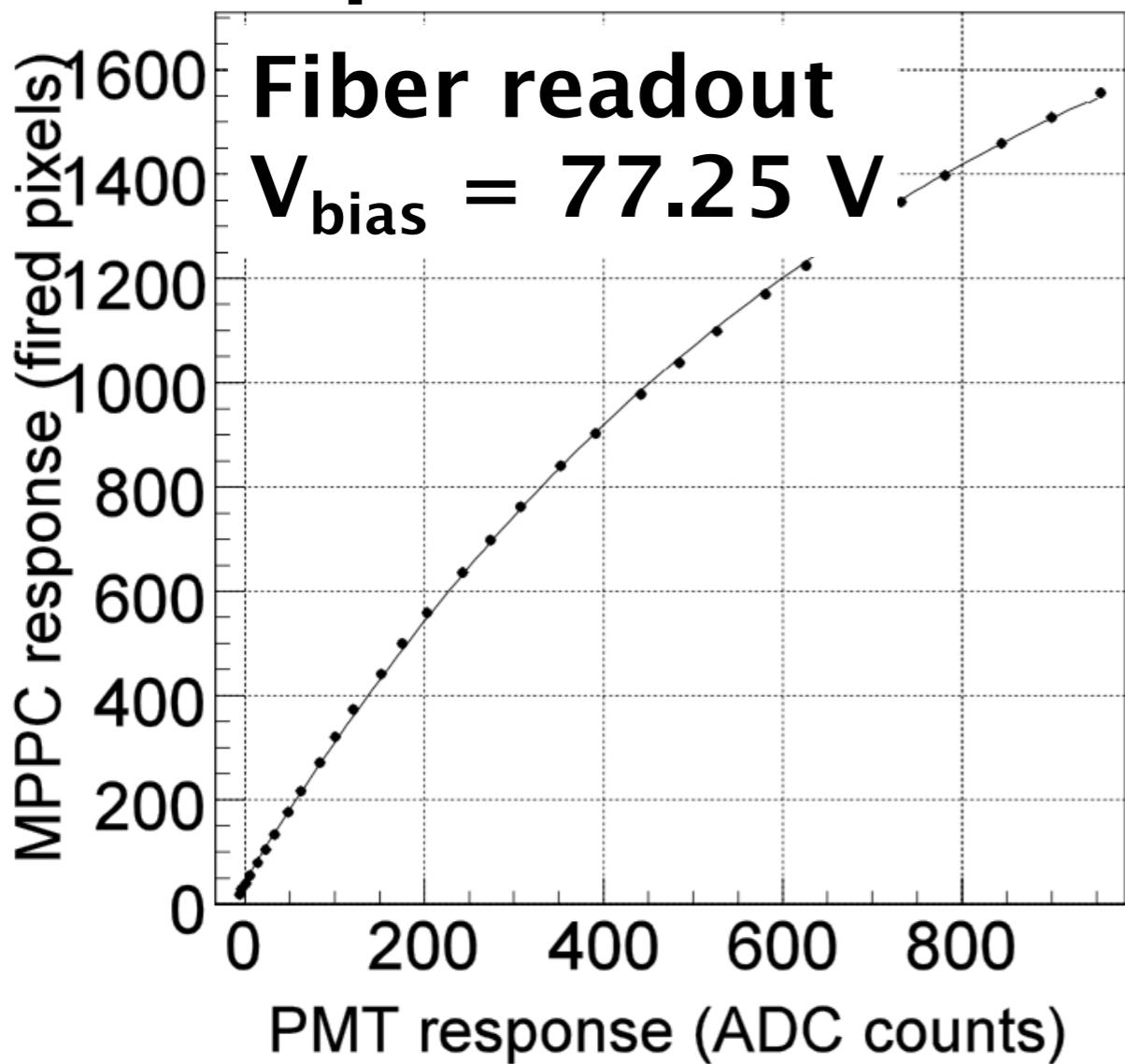
light injection through clear fiber with
notches



R&D Status of the 1600 pixel MPPC

	Performance	status
Gain	$10^5 \sim 10^6$	OK
Photon Detection Eff.	~0.2 for 1600 pix. MPPC	OK
Dark Noise Rate	~ 100 kHz	OK
Photon counting	Great	OK
Bias voltage	~ 70 V	OK
Size	Compact	OK
Dynamic range	Determined by # of pixels and recovery time	underway
Cost	Expected to be < \$10	Negotiating
Long-term Stability	Unknown	Not checked
Robustness	Unknown, presumably good	underway
B field	Expected to be Insensitive	Not checked
Timing resolution	Expected to be 0.1~1 ns	Not checked

Response Curve Measurement



$N_{\text{pix}} = 1988.9 \pm 42.5$
 $s = 2.77 \pm 0.06$
 $\Delta_{\text{ped-PMT}}$
= 19.7 ± 15.3 (ADC counts)
 $\Delta_{\text{ped-MPPC}}$
= 100.1 ± 42.4 (ADC counts)

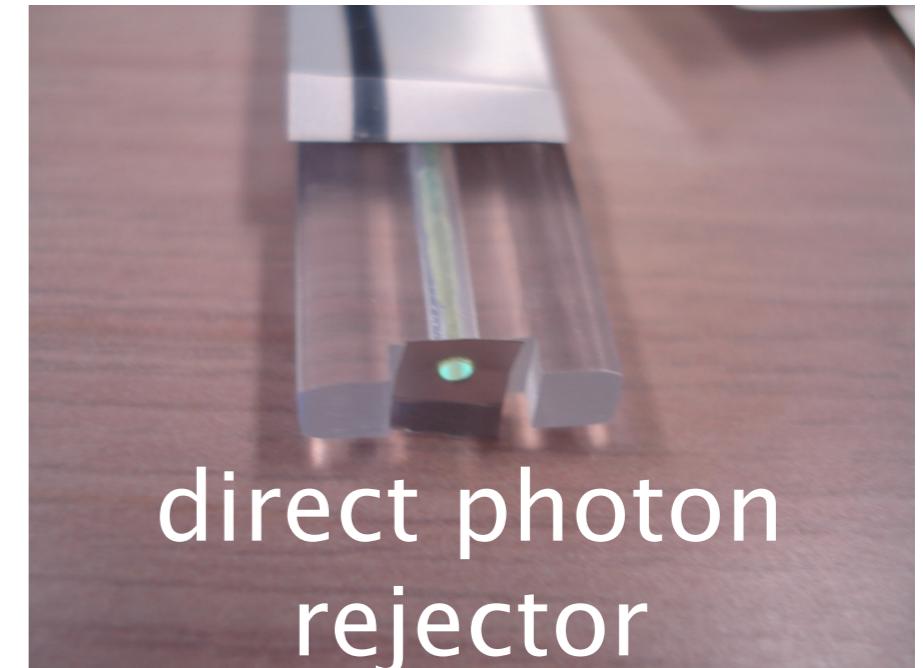
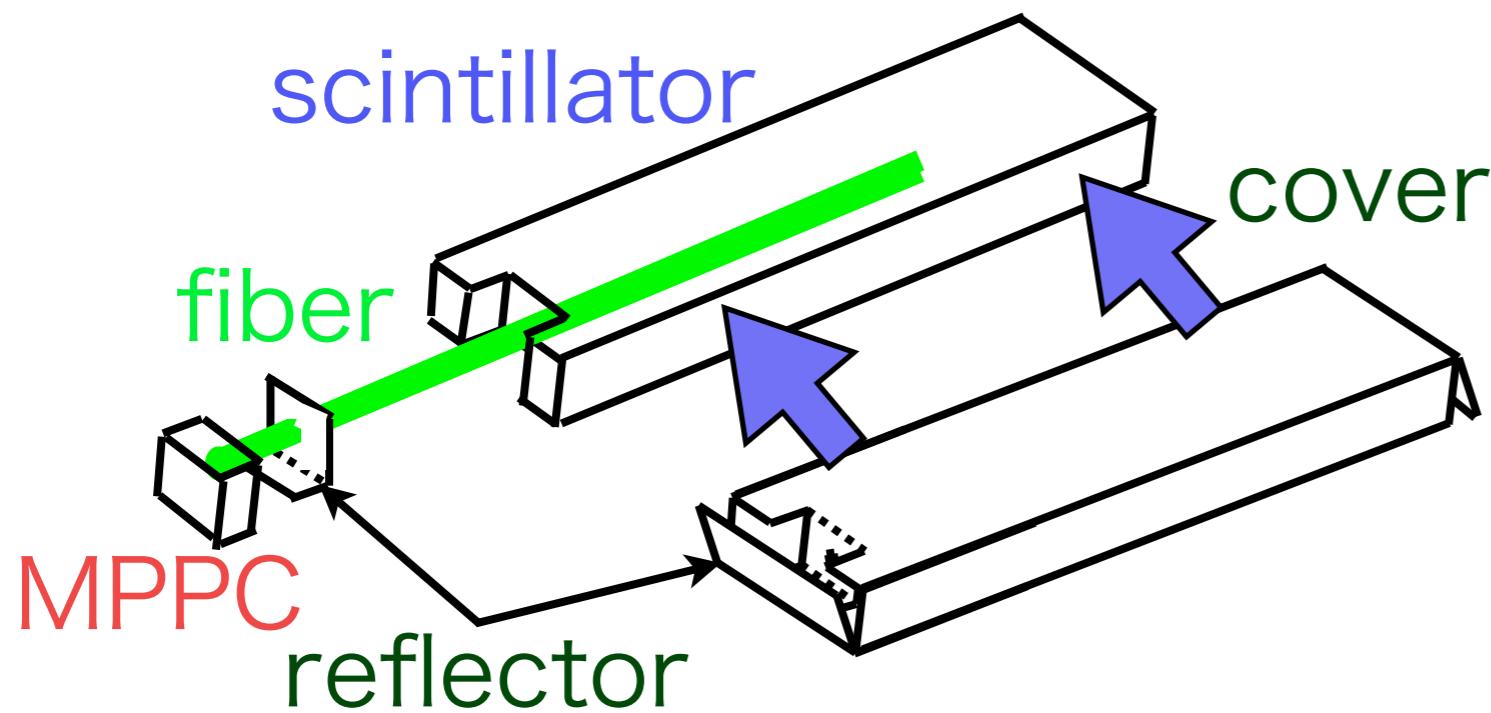
$$N_{\text{fired}} = N_{\text{pix}} \left\{ 1 - e^{-s \cdot (\text{ADC}_{\text{PMT}} - \Delta_{\text{ped-PMT}}) / N_{\text{pix}}} \right\} + \Delta_{\text{ped-MPPC}}$$

N_{pix} ... “effective” number of pixels

$s = N_{\text{p.e.}} / \text{ADC}_{\text{PMT}}$... scale factor of x-axis

$\Delta_{\text{ped-PMT}}, \Delta_{\text{ped-MPPC}}$... pedestal correction

Such sci.strip should be...



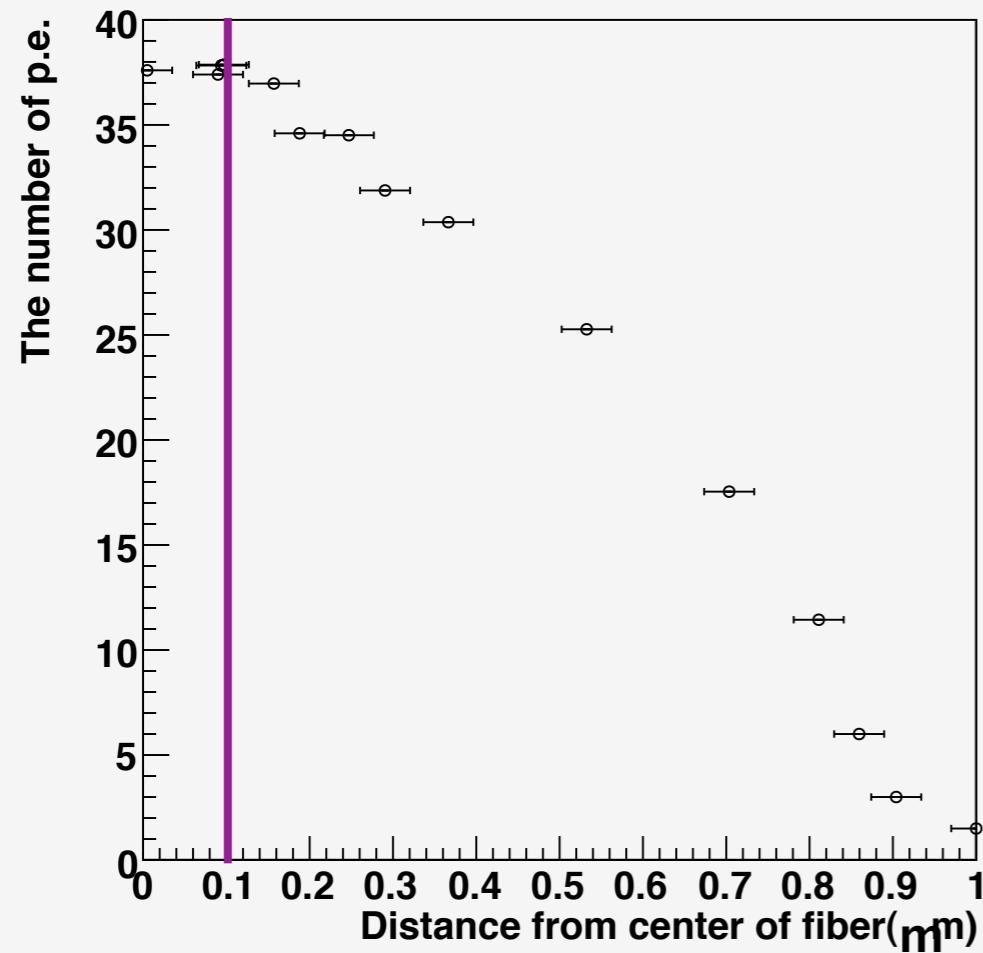
it should be enclosed with reflector film.

- To get enough photon
- To suppress optical cross talk

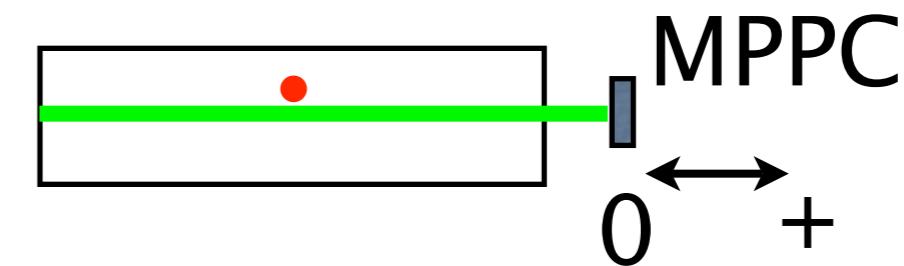
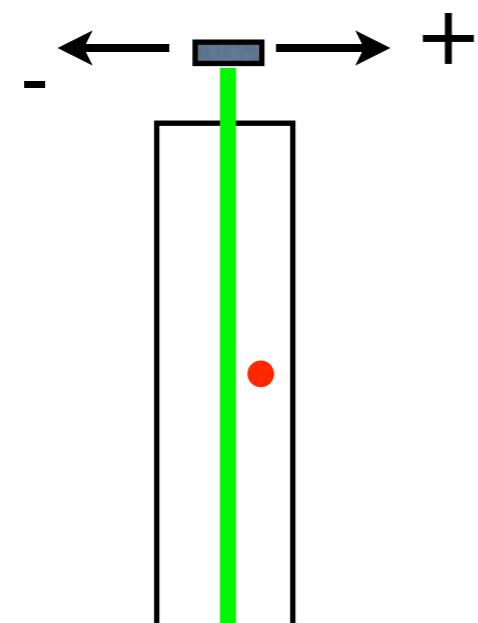
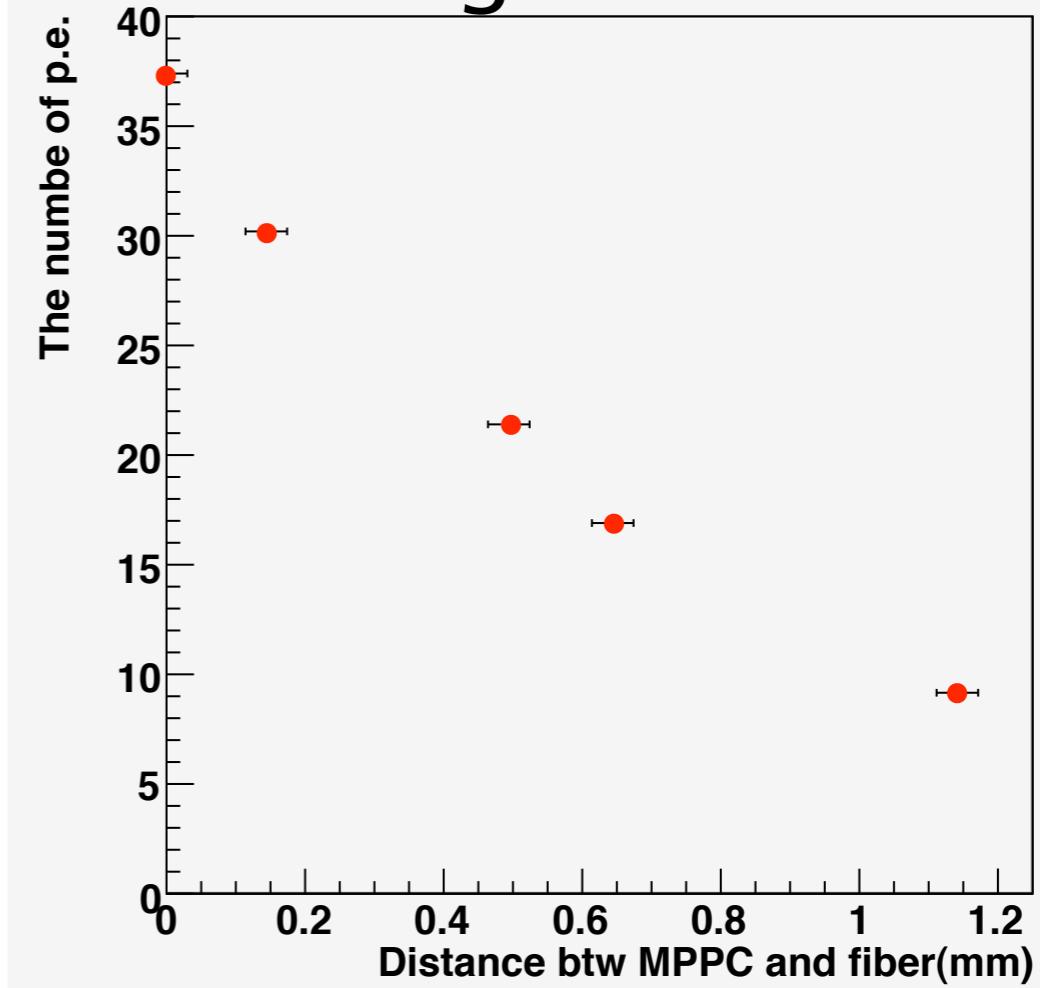
it needs to have reflector to reject photons not through fiber into MPPC sensitive area.

Dependance on MPPC - Fiber matching

Transverse

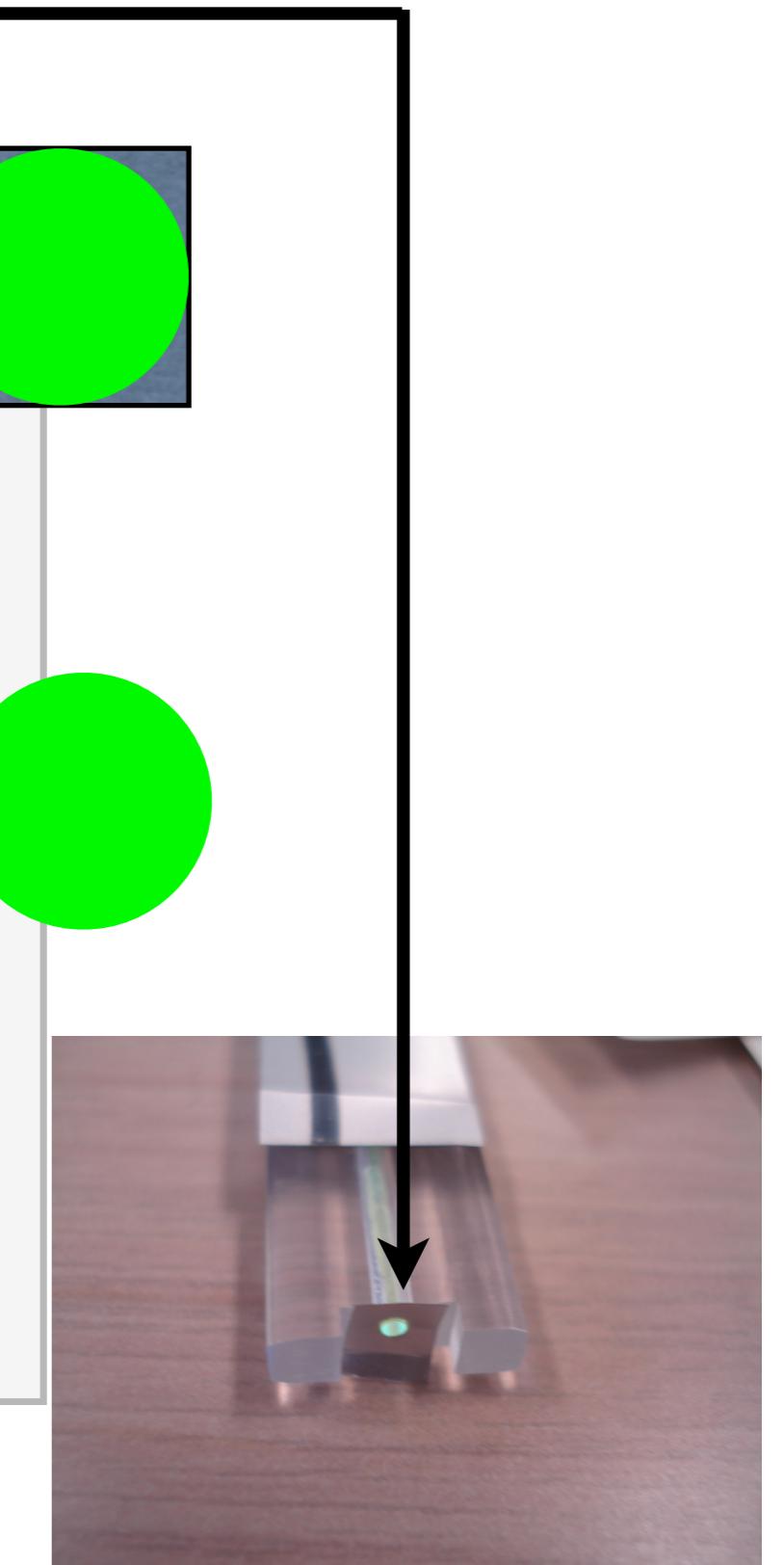
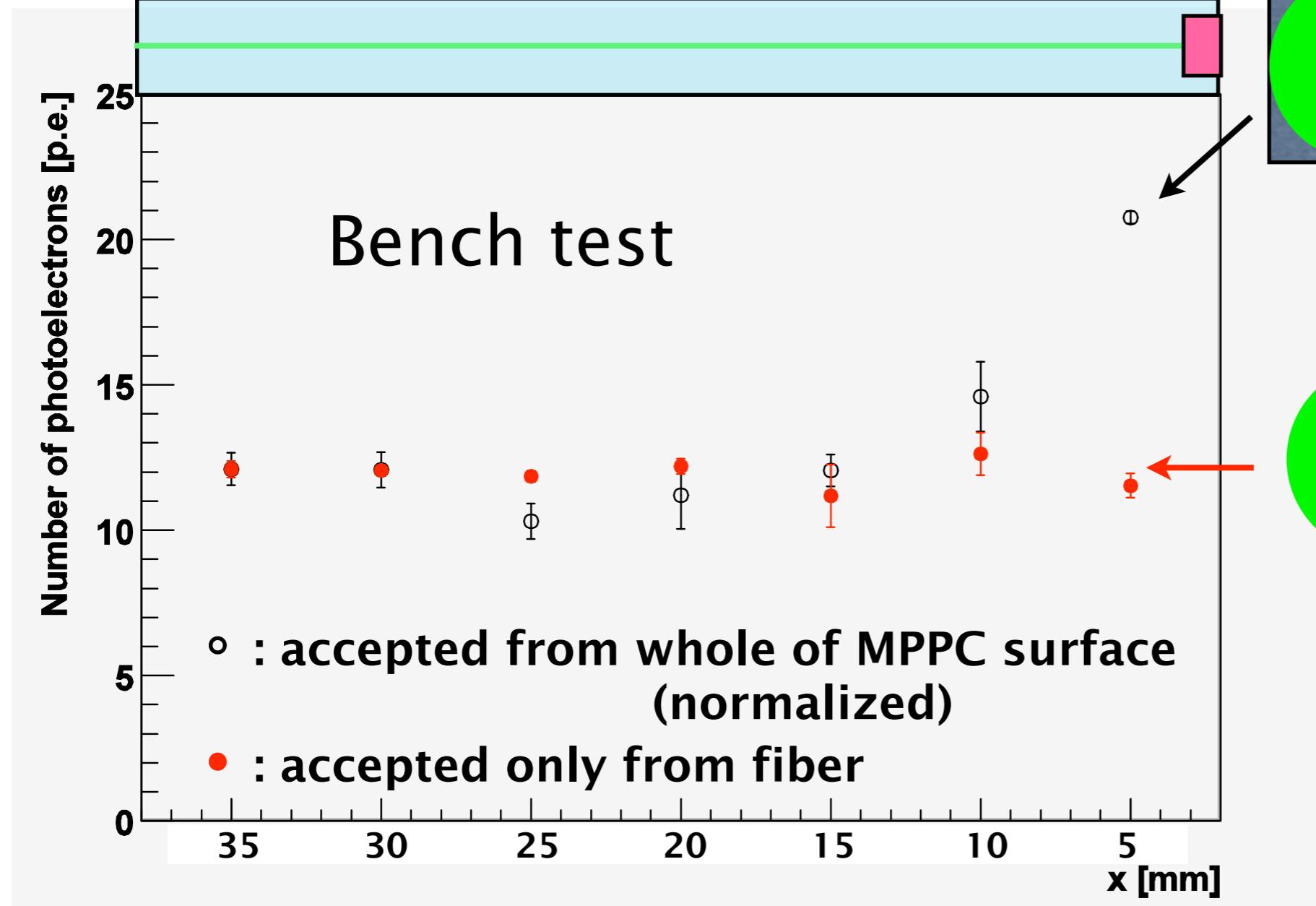


Longitudinal

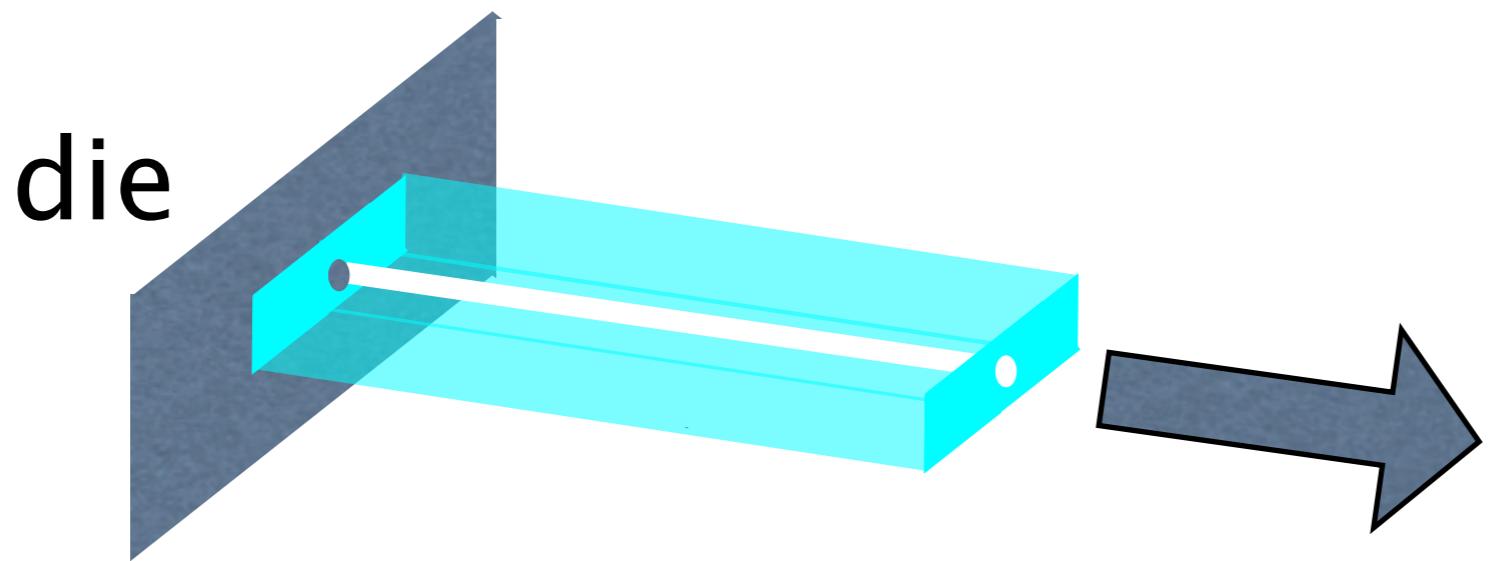


Longitudinal effect is serious!

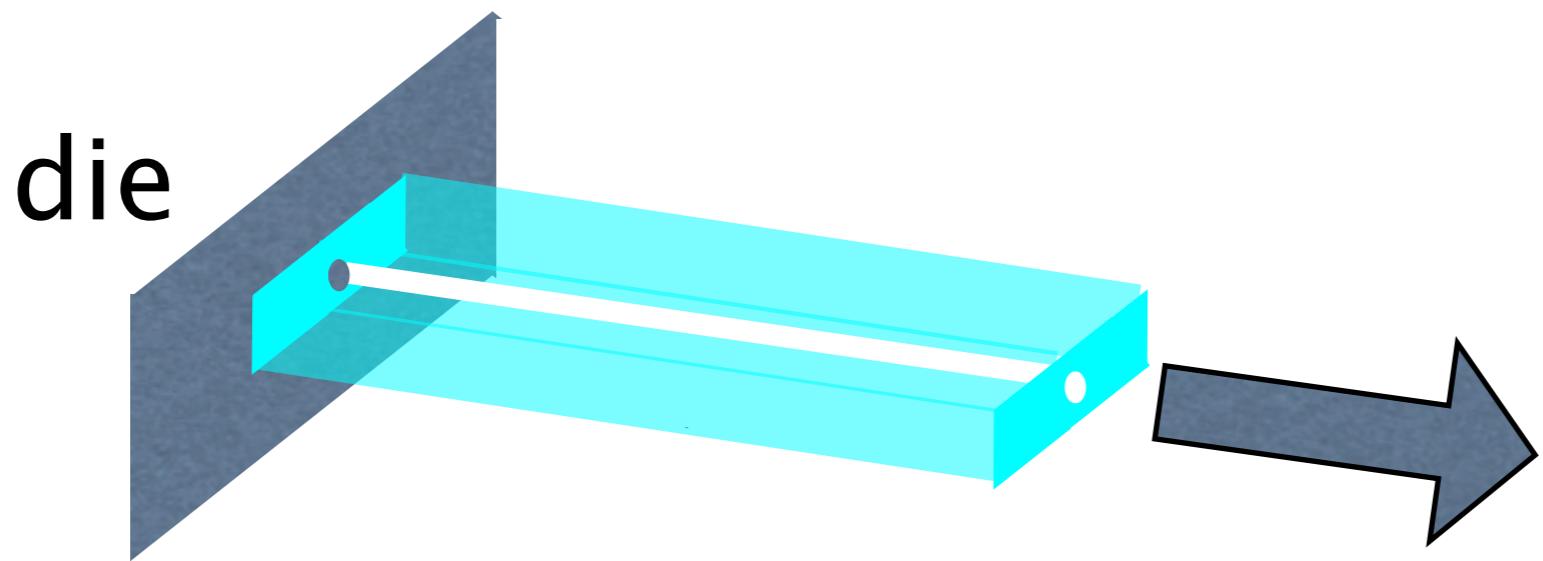
This is the direct photon rejector.



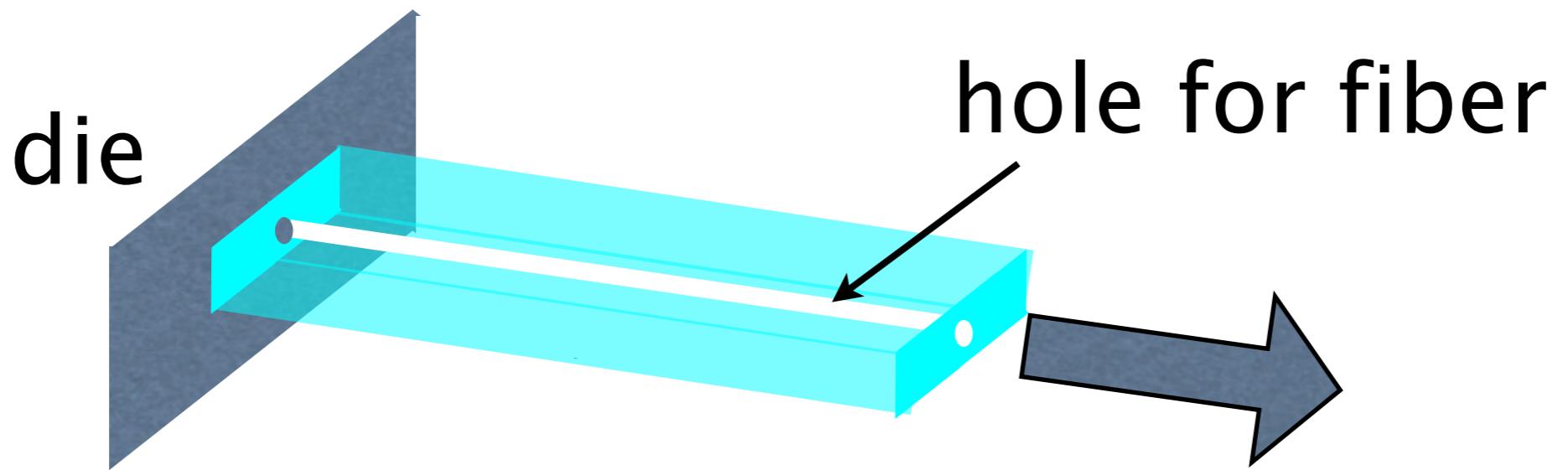
Extruded scintillator



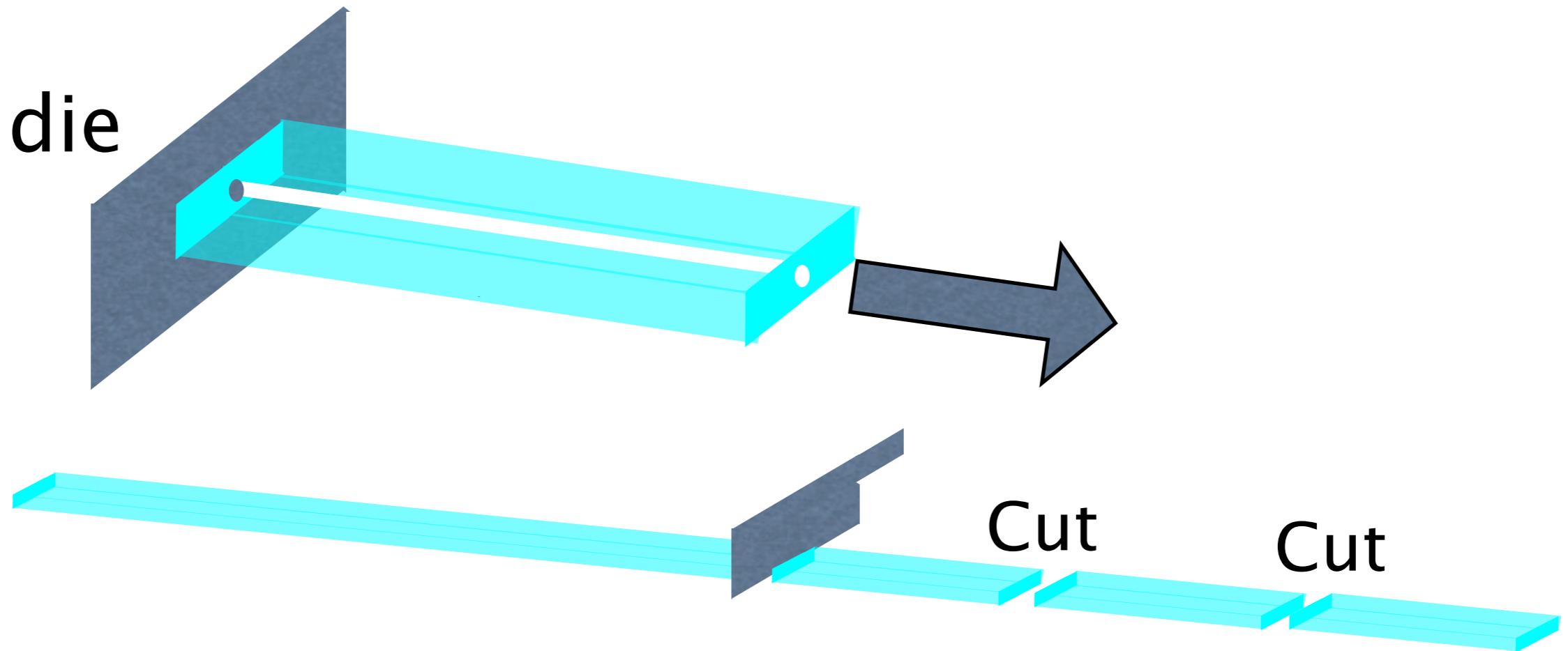
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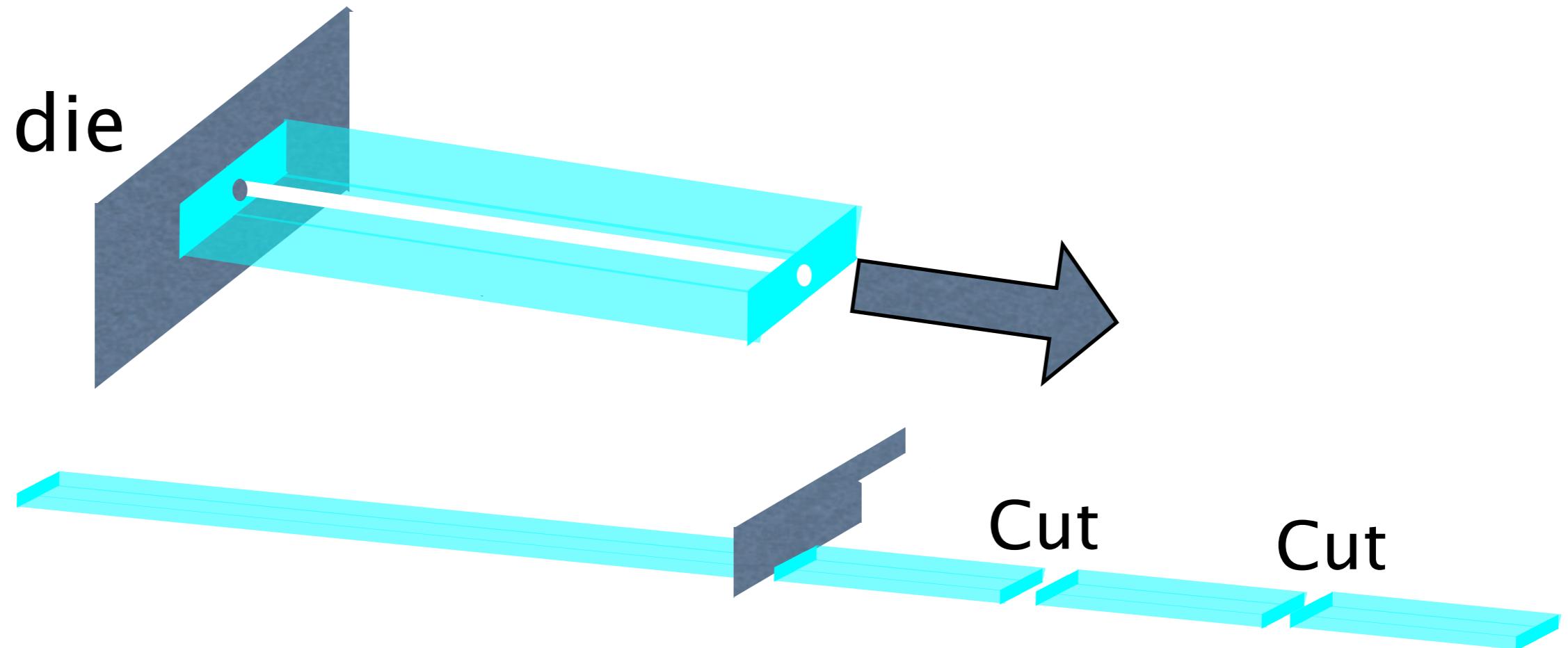
Extruded scintillator



Extruded scintillator

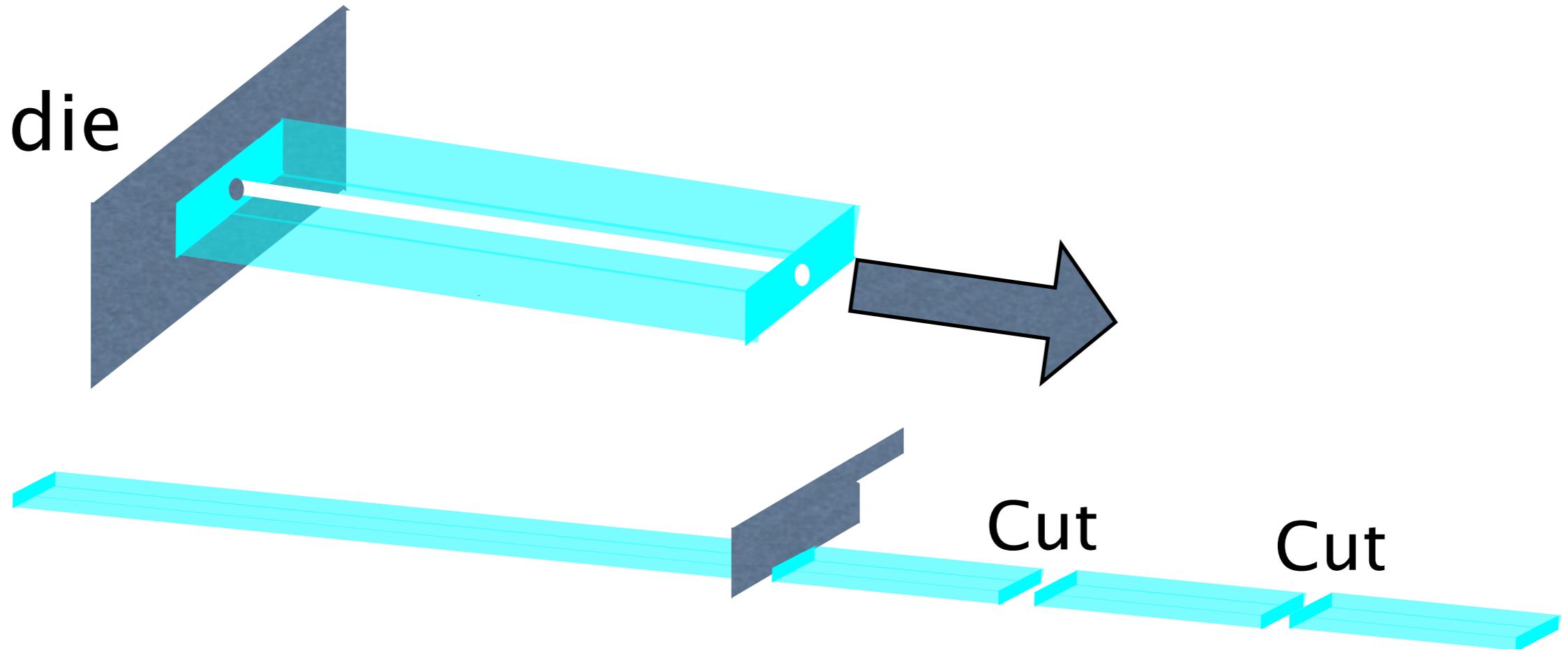


Extruded scintillator



- Symmetry along the longitudinal direction of strip scintillator allows us to use extrusion method.

Extruded scintillator



painting some reflector is allowed simultaneously

We test white paint (TiO_2)

